Studies on Bionomics and Life-History of Oxya Velox Fab. (Orthoptera : Acrididae) with Reference to the Behaviour of its Hoppers to Ecological Factors

ABSTRACT

THESIS

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BY

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A B S T R A C T

The smaller rice grasshopper, Oxya velox Fab., is a known paddy pest and its infestation on paddy has been reported from several East-African countries including India. A detailed study of its ecology has long been due but, besides a few brief notes it somehow failed to attract the attention of the ecologists.

Both males and females are of medium to small size, females being slightly larger than the males, measuring 2.73 cm and 2.48 cm respectively. There is a broad brown band extending from the upper half of the eyes to the base of the tegmina; vertex often with two diverging brown lines and sometimes the middle of the vertex and pronotum filledup with a brown band. Tegmina is longer than the hind femora which is expanded ventrally; hind tibiae beyond the middle and the first tarsal joints considerably expanded. Hind tibiae are green with two rows of brown tipped spines on the margins of the expanded ventral surface. Since O. velox inhibits the water-logged conditions, these expansions of the hind legs help in swimming. The newly emerged adults are green in colour with the dorsal pigmented band as whitish green which turns brown after 4-7 days of emergence. The bright pigmentation diminishes with the advancement of age and just a day or two before death the adults become almost brown. The change in pigmentation is more pronounced among the females

than the males and it may help in speculating the growth potential of a population in the field. The longevity of the males is greater than the females being 39.80 ± 1.57 days and 29.90 ± 1.68 days respectively at 30 ± 1°C, 70 ± 5% R.H. with Cynodon dactylon as food.

Males and females both do not start copulating immediately after the emergence. O. velox adapts the most common type of posture (riding) during copulation. It is completed in 2-4 hours and is repeated several times before or after each oviposition. The females with males in-copula may continue to feed crawl or even jump on disturbance. The frequent copulations are not necessary for the successive ovipositions, however, it has a favourable affect on the fecundity. The female at an average copulates 5 to 6 times during the whole life-time and the average pre-copulation period is found to be 3.40 ± 0.15 days at 30 ± 1°C and 70 ± 5% R.H.

The female of O. velox deposits its eggs in the moderately damp soil and makes a selection of the site with the help of the antennae, palpi and the ovipositor valves. The former two detect the moisture level while the third the compactness of the soil bed. A burrow 1 to 2.5 cm deep is prepared for deposition of the egg-pod and the complete act of oviposition takes 30 to 60 minutes. The average pre-oviposition (maturation), oviposition and post-oviposition periods are 9.0 ± 0.39, 17.0 ± 1.70 and 3.8 ± 0.61 days respectively at 30 ± 1°C and R.H. 70 ± 5%.

The female of O. velox generally deposits eggs in the soil

but sometimes the eggs are also glued to the foliage with the help of the same frothy secretion which forms an egg-pod. The egg-pod is dark brown in colour and is usually cylindrical towards its posterior end while the anterior end is pointed. It measures 1.4 to 3.0 cm long and 0.4 to 0.9 cm in diameter and is usually 2-3 chambered. The average number of eggs in each pod is found to be 9.00 (range 7-14) and the average number of egg-pods per female is 0.20 ± 0.41. The total number of eggs laid by a female in its entire life time averages 50.40 ± 3.92 at 30 ± 1°C and R.H. 70 ± 5%. The eggs are placed in 2 rows, each is elongated and cylindrical, roughly banana-shaped, measuring 0.392 cm long and 0.119 cm in diameter. The eggs gradually increase in size as the embryonic development proceeds and measures 0.416 cm x 0.132 cm on the 17th day of incubation. The average incubation period is found to be 20.00 ± 0.42 days and the average percentage of hatching is 89.1 ± 2.30 at 30 ± 1°C and R.H. 70 ± 5%.

All the larvae emerge from a pod in about 10 minutes and the vermiform larva is green in colour measuring 0.48 cm long. Antennae are 0.13 cm long and 12-segmented. There are no traces of the wing-pads and the genitalia appear rudimentary. The newly emerged adults are negatively geotropic and start feeding about 4 hours after emergence. The hoppers undergo six moults to reach the adulthood. An additional moult may rarely be observed among the females only. The duration of the first second and third instars is slightly longer in the females than the males but it becomes prominent in the last nymphal instar where female hopper

takes 11.0 ± 0.20 days as against 8.80 ± 0.17 days for the male to become the adult. The hoppers stop feeding about 16 hours before the moulting and take about 15 minutes to cast off the old cuticle. Proper perching and sufficient space is required especially for the final moult, otherwise, a deformity occurs, particularly in the wings. The total nymphal duration for males and females is 33.00 ± 0.39 and 41.00 ± 0.48 days respectively at 30 ± 1°C and 70 ± 5% R.H.

The hopper is green in colour with a broad white band running from the base of the eyes to the metanotum along the mid-dorsal line. The dotted pigmented lines run almost parallel to each other along the sides of the band till the last abdominal segment. As the development proceeds the hoppers keep increasing in size, white band extends and becomes more prominent, while the dotted pigmented lines get diminished. The wing-buds start appearing from the third instar but the orientation of the wings starts from the fifth instar.

Food preference tests based upon the number of times a plant eaten per 100 presentations along with exclusive rearing on the single food plant revealed that O. velox is a selective feeder and the preference of food changes with the development. The food plants may be arranged in the descending order of favourableness for the development; mixed diet (Oryza sativa, Echinoclon colonum and Cynodon dactylon); Oryza sativa; Cynodon dactylon; Triticum aestivum; E. colonum; Heteropogon contortus; Setaria

verticellata; Zea mays and Pennisetum typhoideum while Trifolium alexandrinum was not nibbled at all.

The preference of food is based upon the factorial complex including the physical factors, availability of the plants and lastly the chemical composition. The early instar hoppers prefer the weeds while it gradually shifts to the cereal crops as the development proceeds. Thus de-weeding from the fields and especially along the raised margins, could check the population of C. velox to quite an extent.

The food plants of the lesser preferential value reduce the fecundity along with the percentage of hatching while the longevity is increased among both the sexes, but the females survive in a greater number and for a longer period on an unpreferred food plant than the males.

The maximum fecundity with highest percentage of hatching was obtained on the mixed diet, being 80.7 ± 0.88 eggs per female with 90.50% hatch respectively as against the minimum of 13 eggs per female with 30.30% hatching on Pennisetum typhoideum which is the least preferred food.

The effect of temperature and humidity on the various developmental stages was studied by exposing eggs, hoppers and the adults to 10°, 15°, 25°, 30°, 35°, 40° and 45°C and 40 ± 5%, 70 ± 5%, and 90 ± 5% R.H. The eggs were also incubated with 0.0%, 8%, 12% and 25% contact moisture with various temperatures.

The developmental rate of the eggs is enhanced with a rise in temperature; shortest incubation period was at 40°C being 15.20 ± 1.12 days with 8% contact moisture, whereas the maximum percentage of hatching (91.20 ± 1.01%) was obtained at 35°C with 12% contact moisture. Below or above 35°C the percentage of hatching was adversely affected. Too low (0.0%) and too high (25%) a level of contact moisture led to the total egg mortality irrespective of the temperature level. The first 10 days after the oviposition were important when sufficient amount of contact moisture was necessary for the development. A short exposure to 5°C acted as stimulus for development while on increasing the time of exposure the same temperature became lethal. The eggs in the advanced stages of development were not affected so adversely by an exposure to the lower temperature as those in the early stages of the development. The prolongation in the incubation period at low temperature helped *O. velox* to pass over the peak winter without risking the life of the young ones.

The rate of development of the hoppers was directly related to the temperature. The longest nymphal duration was 59.00 ± 2.14 and 64.80 ± 1.08 days at 10°C for males and females respectively, as against the shortest at 40°C being 32.00 ± 0.92 and 38.00 ± 0.86 days respectively. The effect of the humidity was obvious in two ways; firstly, the survival range of temperature was greatly reduced at 40 ± 5% R.H. (25°C to 35°C as against 10°C to 40°C at 70 ± 5% or 90 ± 5% R.H.) and secondly, that the greater number of hoppers survived at high R.H. at any level of temperature. The

hoppers could not survive at 45°C irrespective of the R.H. condition. The ideal conditions for the development of hoppers were 35°C with 90 ± 5% R.H. The conditions of temperature and R.H. short of optimum affected male hoppers more adversely than the female hoppers.

Temperature and humidity both significantly affect the development of the adults. Maturation of gonads was in direct relation with the rise in temperature, 10°C was unfavourable for the normal reproductive activity and also at 45°C, the females could oviposit only when the R.H. was 90 ± 5%. Relative humidity did not affect the maturation or oviposition period except at the higher extremes of the survival temperature. The fecundity was highest at 35°C with high humidity. Low R.H. (40 ± 5%) reduced the egg production while at 70 ± 5% or 90 ± 5% R.H. it remained almost the same. The maximum number of eggs obtained was 64.90 ± 1.68 at 35°C with 90 ± 5% R.H. Within the range of 15°C to 35°C the rise in temperature increased the egg production but a further rise to 40°C or 45°C markedly reduced it. The effect of temperature on the longevity was a bit different. At 10°C the adults survived for a short period, being 15.00 ± 0.82 and 13.90 ± 0.94 days at 90 ± 5% R.H. for females and males respectively. It indicated that females can withstand the stress of low temperature better than the males and also that high humidity at such a low temperature was helpful. The life span was longest at 15°C for both the sexes being 49.20 ± 1.46 and 41.10 ± 1.28 days with high humidity, which reduced with the rise in temperature but a change in temperature from 30°C to 35°C did not affect

the longevity. The low humidity (40 ± 5% R.H.) reduced the life span at each temperature, otherwise the R.H. level of 70 ± 5% and 90 ± 5% did not have any effect. The maximum percentage of survival was obtained in the range of 30°C to 35°C with high humidity. However, it was interesting to note that the favourable temperatures for fecundity, longevity and survival did not coincide and also that the adverse conditions reduced the egg count and not the oviporitional instances.

The reactions of all the nymphal instars to a gradient of humidity, temperature and light were studied in an alternative humidity chamber. It was revealed that the hoppers of C. velox always preferred the wet half of the chamber and the intensity of positive reaction was further increased either at high light intensity, high temperature or both. The hopping activity was more among the early instar hoppers than the late instars. The general activity along with the hopping was influenced by both high light intensity and high temperature. Klinokinesis was primarily influenced by the humidity. Since an increased activity was attributed to the unfavourable conditions of light, temperature or humidity, a minimum activity in the wet half, thus suggested a favourableness of the humid conditions where the hoppers were least agitated. The time spent active as against the total time spent in each half was always more in the dry half of the chamber but a definite decrease in activity was observed at low temperature (15°C) or low light intensity (0.7 log. foot Lamberts). Hence it may be deduced that inactivity could be a better criterion for the

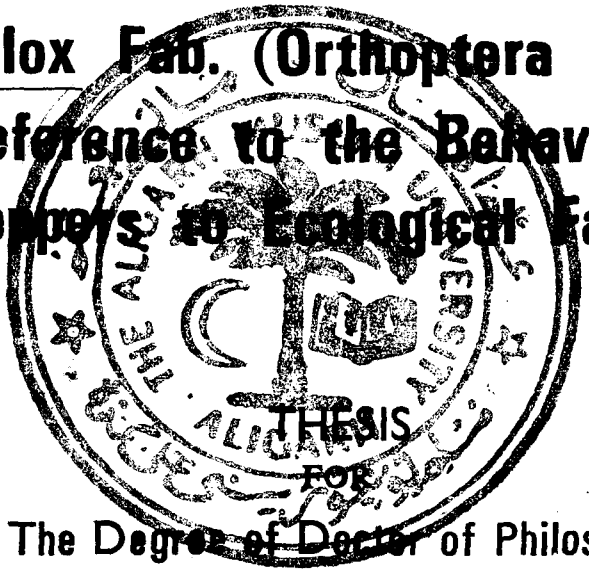
favourableness only when the stresses like low temperature and low light intensity were lacking.

The behaviour of the hoppers in the field was random and undirected. The awakening activity was followed by an ascent before the start of feeding. At mid-day there was a descent and the hoppers as well as the adults were found seeking shelter under the leaves. When the temperature started falling at 10th hour, another spell of activity was observed and the insects were found feeding. During the entire survey none of the hoppers were found resting on the exposed surface of the leaf. The general activity among the hoppers was maximum in the early morning hours and at dusk. There was no aggregating tendency among the hoppers but very young hoppers tended to clutter together in small groups due to the initial cohesion among the hatchlings from the same egg-pod. Moreover, due to their preference for weeds during the early stages of the development, the raised boundaries around the field were infested more by the hoppers.

Hatching in the field occurred in the mid-July till the later half of the August reaching its peak on 30th August. During the rainy season the females out numbered males by 3:2. Throughout the year emergence occurred thrice being maximum, out of the eggs laid by the first generation females, during October through November. The highest peak for the females was on 30th August while that of males on 30th December. There was no diapause among *O. velox*, instead the adverse conditions were passed off by a decrease in the rate of the developmental processes among the various stages.

The present study further revealed that *Oxya velox* Fab. is quite vulnerable as far as the stresses of the environment are concerned and probably due to this characteristic it remained as a sporadic pest in Aligarh District, Uttar Pradesh. The same may hold true for the other tropical countries as the climate does not remain so stable.

Studies on Bionomics and Life-History of *Oxya Velox* Fab. (Orthoptera : Acrididae) with Reference to the Behaviour of its Hoppers to Ecological Factors



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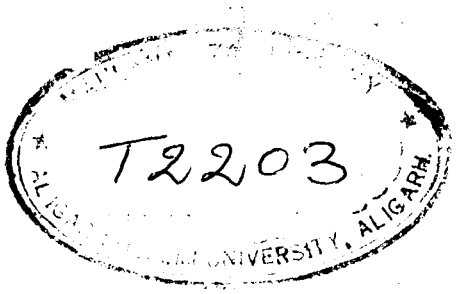

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Dated.....

This is to certify that Mr. Jamal A. Azis has completed his research under my supervision for the degree of Doctor of Philosophy of the Aligarh Muslim University, Aligarh. His thesis entitled "Studies on bionomics and life history of Oxya velox Fab. (Orthoptera;Acrididae) with reference to the behaviour of its hoppers to ecological factors" is an original contribution and a distinct addition to the existing knowledge of the subject. He is allowed to submit this work for the Ph.D. degree of the Aligarh Muslim University, Aligarh.

(Dr. S.A. Azis)
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C O N T E N T S

Page

A C K N O W L E D G E M E N T

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(JAMAL A. AZIZ)

CHAPTER - I

INTRODUCTION

There has always been a struggle between the insect pests and the human beings. Their high incidence of damage has attracted the attention of entomologists for a detailed knowledge about the various aspects of their biology.

Plants are vital for the survival of the mankind, and therefore, heavy losses inflicted on the former would obviously affect the food resources of the latter. The environment plays a very important role in determining the population density of the insect pests. Entomologists have been studying the effect of environmental factors on the development, reproduction, survival and abundance of different stages of there pests.

Members of the superfamily Acridoidea, feed voraciously on the green vegetation. Thus, along with the phenomenal increase in the population and limited food resources man cannot afford to sustain such heavy losses.

The smaller rice grass-hopper Oxya velox Fab. is one of the serious pests of paddy crop. Ramachandra Rao (1921) has reported a crop damage as much as 20 per cent by this pest. It is widely distributed in India, Japan, China, Malaysia and Java. In India it is reported from Andhra Pradesh, Maharashtra, Madhya Pradesh, Orissa, Utter Pradesh, Punjab and Rajasthan.

Lefroy (1909); Fletcher (1917); Ramachandra Rao (1921);

Muir and Fwezey (1927) and Uvarov (1928) have reported its infestation on sugarcane, wheat and maize.

Srivastava (1964) has reported its occasional incidence on Cotton leaves, Varkul leaves, Bamboo leaves, Sotha grass, and certain leguminous crops.

Aziz and Rizvi (1967) have reported this pest on medicinal plants - Solanum nigrum, Datura stramonium (Solnaceae), Ricinus communis (Euphorbiaceae), on vegetables - Solanum melongena (Solanaceae); Hibiscus esculentus (Malvaceae); Cucumis sativus (Cucurbitaceae); Luffa aegyptiaca (Cucurbitaceae) and on weeds - Achyranthus aspera (Lyperaceae); Tribulus terrestis (Zygophyllaceae); Abutilon indicum (Malvaceae).

The present author has found this grasshopper attacking, Sorghum vulgare; Pennisetum typhoideum and Trifolium alexandrinum among the forage crops; only paddy among the cereal crops and Echinocloa colonum; Heteranthria compressa; Setaria verticellata and Cynodon dactylon among the weeds, which are commonly present among the paddy fields.

The weeds are found to be infested by early instar hoppers more than the late instar hoppers and adults. In recent years the extent of damage has increased so much that it has become a pest of considerable importance.

Considerable amount of work has been done on the bionomics and life history of Acridid pests. Observations have been made on the behaviour of Acridid pests in relation to light, temperature and humidity. Despite its great economic importance, no detailed work has been undertaken so far on the bionomics and life history of Oxya velox Fab. However, some information is available on the allied species of Oxya.

The present author has made an attempt to study the bionomics and life history of Oxya velox Fab. with special reference to the behaviour of its hoppers to the ecological factors. Field observations were also made for a period of two years, from January 1973 to March 1975, and were compared with the observations made under the laboratory conditions.

The present work has been divided into three main parts:

1) First part deals with the bionomics and life history of Oxya velox Fab. under constant ecological factors.

2) The second part includes the observations on the development of various stages under different levels of ecological factors.

3) The third part includes the observations on the behaviour of hopper instars to ecological factors.

CHAPTER - II

REVIEW OF LITERATURE

The devastating locust plagues attracted the attention of acridiologists and introduced the study of the members of the family Acrididae as a significant subject since ancient times. The number of studies steadily increased during the second half of the twentieth century.

The biological aspects of the Acridid pests have been studied by Kunkel d'Herculais (1893-1905); Lesseler (1905); Rao (1921) Ivanova (1925, 1926); Ronan and Pakuda (1926); Fedorov (1927); Muir and Fwezey (1927); Uvarov (1928, 1943, 1948, 1966); Boldyrev (1929, 1946); Parker (1929, 1930); Lui and Li (1933); Golding (1934, 1948); Maxwell-Darling (1934); Faure (1935); Kimashiro (1935); Nishikawa (1935); Key (1936, 1938); Roonwal (1936, 1937, 1954); Hamilton (1936, 1950); Hebard (1937a); El Zoheiry (1937); Janone (1938, 1939); Kyl (1938); Chesler (1938, 1939); Pruthi and Bigam (1939); Kennedy (1939); Tinkham (1940); Thotwell (1941); Chauvin (1941); Burtt and Uvarov (1944); Husain et al. (1940, 1946); Celt (1949, 1952); Dirsh (1950, 1956, 1961); Norris (1950, 1954, 1962, 1968); Waterston (1951); Joyce (1952); Katiyar 1952, 1955, 1956, 1961); Albrecht (1953); Richard and Waloff (1954); Agrawal (1955) Antoniou and Hunter-Jones (1956, 1960); Shulov (1952, 1956); Nakhla (1957); Khalifa (1957); Chapman and Robertson (1958); Sharan (1958); Choudhuri (1958); Hafez and Ibrahim (1958); Popov (1954, 1958); Chapman (1959, 1961, 1965, 1972); Hilliard (1959); Hunter-Jones and Ward (1959); Stower (1959); Pickford (1960, 1966, 1970); Dudley (1961); Gregory (1961); Hartley (1961); Hunter-Jones and Lambert (1961); Pradhan and

Peshwani (1961); Chulov and Pener (1961, 1963); Arhall and Ellis (1962); Dempster (1963); Dadd (1963); Jago (1963); Hunter-Jones (1964); Putnam and Handford (1964); Gregory (1965a & b); Edwards and Epp (1965); Hogan (1965); Jacobson (1965); Riegert (1967); Grewal and Atwal (1968); Phipps (1968, 1970); Smith (1968); Moriarty (1969); Harjai and Pikka (1970); Pariher (1971); Pickford and Gillott (1972); Antoniou (1973); Riek (1974); Iqbal and Aziz (1974); Majeed and Aziz (1975) and Moonis and Aziz (1977).

The increase in body weight in accordance with the sexual maturation as well as its subsequent fluctuations throughout the life has been studied by Phipps (1950) on Locusta; Norris (1954, 1959a) on Schistocerca gregaria and Nomadacris septemfasciata and Richard and Waloff (1954) on Omocestus viridulus.

Lui and Li (1933) found that pre-copulation period lasted for 15 to 41 days in Oxya chinensis. Hishi Kawa (1935) observed that pre-copulation period in Oxya species varies from 9 to 25 days. The male Poecilocerus pictus has a longer pre-copulatory period where as female is copulated just after its emergence (Pruthi and Nigam, 1939).

The mode of copulation among Acridids has been reported in detail by Fedorov (1927) in Anacridium aegyptium; Boldyrev (1929) in Locusta migratoria; Kyl (1938) in Melanoplus differentialis; Pruthi and Nigam (1939) in Poecilocerus pictus; Katiyar (1952) in Hyprepocnemis roseus; Norris (1954), Hunter-Jones (1960) in Schistocerca gregaria; Gregory (1961) in Locusta migratoria and

Pickford and Gillett (1972) in Melanoplus sanguinipes. The act of copulation is followed after more or less an elaborate courtship behaviour. The most common method is 'Riding' where the male mounts over the female, clasping her firmly with first two pairs of legs. The hind pair does not take any direct part during the whole process. The tip of the male abdomen is then bent down and brought under the female abdomen to facilitate introduction of penis between the ventral ovipositor valves of the female (Uvarov, 1966).

Katiyar (1952, 1956b) distinguished two other types of postures 'Lateral' and 'Hanging' especially in such forms where ratio of the male and female length was high. Popov (1958) observed in Schistocerca gregaria that the copulating females may continue to feed, crawl or jump.

According to Pickford and Gillett (1972) the selection of the mate in Melanoplus sanguinipes is influenced by aggressiveness of male, docility of female and production of chemical attractants by female. In most of the members of the sub-family Acridinae and Oedipodinae certain body parts like antennae, palpi, cerci, sense organs and chemical stimuli along with female sex attractants play an important role in the courtship activity, where as the accoustical means of communication are used during the sexual activity (Criddle, 1933; Kyl, 1938; Jacob, 1953; Perdeck, 1958; Haskell, 1958; Jacobson, 1965; Thomas, 1965; Uvarov, 1966; Loher and Chandrashekaran, 1970; Ottoe, 1970; Pickford and Gillett, 1972).

The duration of copulation varies from species to species. Fedorov (1927) in Anacridium aegyptium observed the pairs incopula for 19 to 60 hours. Repeated copulations before the oviposition have been observed by several workers, but Norris (1954) observed that single copulation was sufficient to fertilize a number of egg-pods in L. gregaria. Hunter-Jones (1960) observed instances of repeated copulations in Schistocerca before the oviposition but the last copulation was the effective one.

The nature of the soil is an important factor for oviposition. The female prefers to lay eggs in the moist soil and in cases where the soil is extremely dry, females failed to oviposit at all (Norris, 1952; Edward and Epp, 1965).

Rao (1921) observed in Oxya velox that the eggs were laid on the foliage of aquatic and other plants under water-logged conditions of the soil. Female Colemania sphenaroides oviposits in black soil (Ovarov, 1929). Joyce (1952) reported that the female Oedaleus senegalensis prefers to lay the eggs in clay. Katiyar (1955) observed in Aularches punctatus the deposition of eggs in sandy loam. Pradhan and Pershwani (1961) observed in Hieroglyphus nigroreplietus Bol. that the eggs were laid in the roots of various shrubs. Moriarty (1969) reported a decline in the egg laying capacity with the advancement of age in Chorthippus brunneus Thumb.

The female after the selection of site for oviposition makes a burrow with the help of the abdomen in which the eggs were

deposited. The process of oviposition has been described by Fedorov (1927) in Anacridium aegyptium, Pruthi and Nigam (1939) in Poecilocerus pictus, Agrawal (1955) in Aularches punctatus and Parahieroglyphus bilineatus, Hafez and Ibrahim (1959) in Acrida pellucida and Majeed and Aziz (1975) in Gastrimargus transversus. Richard and Wallof (1954) reported the arrangement of the eggs in an egg-pod of Stenobothrus lineatus and Mecostethus grossus.

Roonwal (1936a) in Locusta migratoria reported the gradual increase in the size of the eggs during the course of development with the exception of few highly xerophilous species like Zonthis pulchripennis in which the eggs do not increase in size. (Pavlov, 1952). The variation in size and shape of the egg-ponds is related to the moisture, the food of the parents and the number of egg-pods laid previously (Norris, 1950) and the nature of the soil (Hilliard, 1959).

Riley et al. (1880) in Camnula pellucida, Hunckel (1890a & b) in Dociostaurus and Mikhel'son (1922) in Locusta have lucidly described the process of hatching. The vermiform larva emerges on the surface of the soil and casts off its outer covering membrane called the intermediate moult (Uvarov, 1928). Now the young one resembles the adult in the general form. The number of instars may vary from species to species in Acridids and even among the individuals of the same species. However, some suggestions have been made by Uvarov (1966). According to him the number of instars is inversely proportional to the degree of advancement among the

groups of acridids, thus, suggesting an evolutionary trend in the reduction of the number of instars.

Antoniou (1973) studied the life history of Orthacris turbida Walk. and found that the mean nymphal period of males and females was 59.9 ± 3.8 days and 78.7 ± 3.2 days respectively. There were 6 nymphal instars with the mean maturation period of isolated females being 101 days and that of crowded ones being 73 days. Nick (1974) studied the biology of Stenacris nitreipennis. Marshall, Iqbal and Aziz (1974) studied the life history of Spathosternum parasimilierum Walk. and reported 6 nymphal instars with an average total nymphal period of males and females being 37.58 ± 0.28 days and 44.25 ± 0.883 days respectively. Majeed and Aziz (1975) reported 4 to 6 instars in males and 6 to 7 instars in females of Gastrimargus transversus Thumb. Moonir and Aziz (1977) in Trilophidia annulata Thumb. reported 5 nymphal instars with total nymphal period for males and females at an average being 29.7 ± 0.994 days and 40.4 ± 1.520 days respectively.

The feeding coactions between the Acridids and the different food plants, where latter affect the biological processes of the former have been studied by many workers like Vestal (1913); Hubbel (1922a & b); Criddle (1924); Rubtzov (1932a & b); Criddle (1933); Moore (1936); Strobecker (1937); Isely (1938, 1946); Sanderson (1939); Urquhart (1941); Central (1943); Tauber et al. (1945); Husain et al. (1946); Brett (1947); Davies (1949); Pfadt (1949a); Koshanchikov (1950); Smith (1950); Anderson and Wright (1952); Smith et al. (1952); Noonwal (1953); Scharf (1954); Williams

(1954); Barnes (1955); Pickford (1958); Korelina (1960); Singh (1961); Misra (1962); Haskal and Mordue (1969); Barneys and Chapman (1973); Blaney, Chapman and Wilson (1973); Gangwere (1973); Pandian (1973); Joye (1973); Clark (1974); Hewitt and Rees (1974); Lambert (1974); Coswell and Reed (1975); Otte (1975); Moorehouse, Bartonbrown and Vangerven (1976).

Vertal (1913); Rubbel (1922a & b); Urquhart (1941) and Cantral (1943) observed that the distribution of the grasshoppers in North America was related to the type of vegetation and further that the controlling factors were entirely phytical. Davies (1949) showed that the nymphs and eggs of Melanoplus mexicanus and Melanoplus differentialis were 40% less abundant in grassy field margins than the weedy ones. Anderson and Wright (1952) found that the distribution of grasshopper species in Montana was not at random but dependent upon the vegetation. Misra (1962) found that the nutritional composition of plants is more important for controlling the distribution than the physical factors alone.

Clark (1974) suggested that the rain favors the survival of the nymphs immediately after hatching by influencing the growth of the food plants.

The preference of food and its affect on the course of development is evident as has been reported by several workers. Rubtsov (1932a, b) reported that every plant community has a characteristic grasshopper population and vice-versa, and the

relation between the two is so close that indicator plants could be found for grasshoppers e.g. Comphocerus sibericus L. is closely connected with Agropyron cristatum; another grasshopper Chorthippus alboserginatus is associated with Poa pratensis. Criddle (1933) found that Camnula preferred Agropyron smithi, Poa pratensis, Hordeum jubatum and Bromus inermis. Tauber et al. (1945) observed that dry Alfa-alfa did not support the life of Melanoplus bilineatus for long, but if excess of water was provided, grasshoppers could live on dry food. Isely (1938, 1946) gave a detailed account of feeding of the grasshoppers in Texas indicating that the grass feeders starved on forbs and the forb feeders on grass. Husain et al. (1940) and Roonwall (1953) observed that locusts prefer succulent food over papery one. Williams (1954) studied the food preference of some British Acridids and found that succulence of food was of prime importance and not the toughness of the blade. Pfadt (1949a); Smith (1950); and Barnes (1955) reported that Melanoplus mexicanus was a forb-feeder, flourished and produced maximum number of eggs on Sunflower, Barley, Dandelion, Alfa-alfa, Kentucky blue grass, Brome, Russian thistle and Pigweed. Singh (1961) found that Chrotogonus trachypterus preferred Trifolium alexandrinum, Lycopersicum esculentum, Solanum tuberosum, Solanum melongena and Cucumis melo utilissima over Calotropis procera and Carthamus oxycantha where only flowers were eaten.

In some grasshoppers the preference of food changes with the growth stages of the food plants as well as that of the grasshoppers. Rubtzov (1932a) stated that the range of preference of food plants generally increases with the development of the grasshoppers. Moore (1936) observed that Camnula did not feed upon Agropyron smithi in the spring or fall, but in the next season it appeared to be the favourite plant. Scharff (1954) observed that all nymphal instars of Melanoplus mexicanus preferred Bromus tectarum (Downy chess) while adults feed on some other grasses and forbs. Misra (1962) stated that Camnula pellucida discriminates nutritionally favourable and unfavourable plants but he did not adduce enough evidence in support of this contention.

Criddle (1924) found that wandering jew is particularly suitable for rearing Melanoplus mexicanus. Sanderson (1939) observed that Melanoplus differentialis Thos. developed faster with high survival rate and laid more eggs when reared on soyabean plants than on cotton. This grasshopper, when fed on Burmuda grass, did not develop beyond first instar. Pfadt (1949a) found significant difference in the size of the teneral adults and in their nymphal duration which was shortest on the most favourable diet. Kozhanchikov (1950) found that more primitive groups of Acrididae feed mainly on the lower dicotyledons, while the more advanced Oedipodinae feed on monocotyledons. Brett (1947); Smith et al. (1952) and Barnes (1955) studied the effect of food on the survival, fecundity and growth of Melanoplus mexicanus and agreed with the findings of Pfadt (1949a). Barnes (1955) observed

better development of Melanoplus sanguinipes when fed on mixed diet of Alfa-alfa and weeds. He studied 19 single plant and 4 two plant diets to observe the effect on nymphal development of Melanoplus sanguinipes and found that alternating one favourable with one unfavourable plant gave results almost as good as those obtained with one favourable plant exclusively.

In recent years notable contributions on the feeding habit and food preference have been made by Haskel and Mordue (1969); Blaney, Chapman and Wilson (1973); Barnes and Chapman (1973); Gangwere (1973); Pandian (1973); Toye (1973); Hewitt and Rees (1974); Lambert (1974); Coswell and Reed (1975); Otte (1975); Moorhouse, Barton Brown and Van Gerven (1976) and Iqbal and Azim (1975, 1977).

The role played by mouth receptors in food selection was studied in Schistocera gregaria with the help of Phagostimulent and deterent factor by Haskel and Mordue (1969) and results obtained were positively significant.

S. gregaria was reared more successfully on grasses than the other types of plants at 28° - 30°C (Toye, 1973). A positive correlation between food availability and food selection has been suggested by Gangwere (1973), and also that availability appeared as important as preference in determining the feeding. Thus in a way contradicting the succulence basis for food selection, as reported by earlier workers.

Pandian (1973) studied the food intake and energy expenditure patterns of Oxya velox Fab. and Bombyx mori, the latter insect showed higher feeding rate, assimilation and conversion efficiencies than the former. The environmental factors influence the pattern of feeding probably through their effect on the locomotor activity in Locusta migratoria (Blaney, Chapman and Wilson, 1973).

Among the Australian plague Locust Chortoicetes terminifera Walk. Lambert (1974) observed that the feeding commenced at 13.5°C air temperature and increased with the rise in air temperature along with the total radiation. He also suggested that in the older adults feeding may be reduced 2-3 hours before the sunset but the younger adults may continue to feed even in the dark till the air temperature does not fall. Hewitt and Rees (1974) observed a change in the habitat of most acridids due to contour, furrowing, scalping and inter-seeding. This change occurred due to changes in the abundance of preferred food plants. Thus emphasising the role of vegetation in distribution. Otte (1975) found that the theory of defence of plants against herbivores was not supported in the ecosystem study taking Schistocerca into consideration and also that the correlation between the level of preference and the ability of plants to support growth with survival is high. Moorehouse, Barton Brown and Vangerwen (1976) tested factors affecting the rate of ingestion of liquids in Chortoicetus terminifera and found that neither sucrose (having powerful stimulus) nor water intake during the first half of meal was affected. Iqbal and Aziz (1975, 1977) tested the preference of

of Spathosternum parasiniferum against 12 plants and found that early instars prefer weeds over the cereal crops while it is reverse for the adults and the later instars. S. parasiniferum thrived best on the mixed diet of O. sativa and C. dactylon.

It has been pointed out in the reports of the U.P. Entomological Commission (1907) that temperature influences the development of eggs.

Bodine (1925a) observed that exposure to low temperature for a short period interrupted the development for some time, but according to Uvarov (1928) it served as a stimulus for development. He found that hatching is greatly influenced by the alternate exposure to low and high temperatures. Parker (1929) observed a high percentage of hatching in moderately damp soil than in the wet or dry soil.

The eggs in the first few days of incubation absorb sufficient amount of water which is required for the development of embryo and that high or low relative humidity apparently has low effect on the development. Further, the incubation period can be prolonged by checking the absorption of water. It was observed by Husain et al. (1941), Shulov and Pener (1961, 1963) in Schistocerca gregaria, where the eggs after incubation for three days in wet sand were transferred in air and after 90 days were returned to the wet sand, low percentage of eggs hatched proving the possibility of an extension in the incubation period due to deficiency of water. Church and Pelt (1952) observed the

normal development of Melanoplus bivittatus at 12°C. Shulov (1956) found that the eggs of Anacridium aegyptium which normally hatch in about 30 days may hatch after two months due to the water deficiency. Shulov (1956b) observed that one day old eggs of Schistocerca gregaria when exposed to air with 40 - 80% R.H. died within 6 days.

Grewal and Atwal (1960) after incubating the eggs of Chrotogonus trachypterus at different levels of temperatures and relative humidities found that the incubation period was inversely proportional to the temperature where as moisture between 4% and 12% did not have any significant effect.

Shulov and Perer (1963) observed that the eggs placed in contact with water for a few days and later removed, were able to continue the development. However, the development was retarded in the eggs placed in absolute dry conditions. They observed that excess amount of water may also cause egg mortality especially among the species laying eggs in dry soil eg. Dociostaurus and Tmethis. Hunter-Jones (1964) found that eggs of Schistocerca gregaria failed to hatch in water logged condition (25 cc water/100 gms of sand) and almost dry condition (0.6 cc water/100 gms of sand), water contents between the two extremes made no difference. Harjai and Sikka (1970) stated that the soil with very low or high level of moisture had similar effect in prolonging the incubation period.

Uvarov (1973) presented a theory of biotope association based on a complex of factors each of which acts at different phases in ontogeny. The chief factors are temperature and humidity of the oviposition site and the criterion for biotope association is the different sum of temperatures required for successful embryonic development.

Iqbal and Aziz (1973) in F. parasimilierum Walker, and Khan and Aziz (1973) in O. abruptus observed the development of eggs in relation with the temperature and humidity and found that the development is directly affected by temperature.

Notable contributions have been made on hopper development in relation to different levels of temperature and humidity conditions (Parker, 1930; Smee, 1936; Husain et al., 1936; Hamilton, 1936; 1950; Burnett, 1952; Antoniou and Hunter-Jones, 1956, 1958; Pradhan and Pershwani, 1961; Grewal and Atwal, 1968; Parihar, 1971). In American species of grasshopper, Parker (1930) reported that the temperature and humidity accelerate the rate of development and shorten the hopper period. Hamilton (1936, 1950) discussed the effect of different levels of temperature and humidity on hopperal period and found a decrease in the period with the rise in temperature. The optimum conditions for the rate of development and the survival do not coincide, as in Locusta M. migratoroides. Hoppers developed faster at 42.2°C while the highest survival rate was at 34.4°C, but the respective optimum temperatures for Schistocerca gregaria, remaining 30.3°C and 32.2°C. According to Hamilton (1950),

Schistocerca gregaria hoppers complete their development at 32.2°C and 45% R.H. while at 2..1°C and 25% R.H., they fail to develop. (he also observed that the rate of development is slowed down at low humidity than at higher, which is contrary to the findings of Husain et al. (19..) and Chauvin (19.1b) in Schistocerca gregaria. Khan (19.9) studied the development of eggs and larvae of grain weevils (S. oryzae L. and S. granarius L.) in relation to different temperatures and relative humidities. He observed that the rate of development was decreased at low temperature and low humidity. Simultaneously, the duration of larval period increased. The rate of mortality was also high at low temperature and low relative humidity. Grewal and Atwal (19.8) in Chrotogonus trachypterus found that hopper duration at 25°, 30°, 35°C and 40% R.H. was 50.7, 44.1 and 38.8 days respectively, but increase in relative humidity to 70% reduced the hopperal duration i.e. 4..5, 42.2 and 33.8 days at respective temperatures. The lowest survival percentage was observed at 40% R.H. Antonion and Hunter-Jones (19..) found that the hopper duration at 20°C in Lyprepocnemis capitata was 52.0 days for males and ..2.5 days for females. In A. plorans ornatipes at 20°C duration of male hoppers was 37.0 days and 42.0 days in females while in A. plorans meridionalis 52.0 and ..2.5 days for males and females respectively were recorded at the same temperature (Antonion and Hunter-Jones, 19.8). In Hieroglyphus nigroreplotus Bol. it was reported by Pradhan and Perhwani (19.1) that hopper development was completed in 71.0 days at 2..°C while at 32.5°C

it took only 35.1 days. Development did not complete at 20°C and 40°C. Similar results were obtained by Parihar (1971) in Poecilocerus pictus where at 25°C, 30°C, 35°C and 40°C the rate of development was accelarated with the rise in temperature from 25°C to 35°C. The temperature beyond 35°C was unfavourable and no hopper could complete the development at 40°C.

The number of hopper instars in acridids varies from species to species. Chesler (1938) reported that males and females pass through five instars in Oedaleus nigrofasciatus. In O. johnstonii the number of instars varies from 7 to 10 (Joyce, 1952). Brezhkov (1956) in O. decorus reported five instars in both sexes. The number of hopper instars in E. bolivarensis was 6 in male and 7 in female (Tinkham, 1940). Antonion and Hunter-Jones (1956) in E. capitata reported 6 instars in males and 7 in females. Nakhla (1957) reported six instars in both the sexes of E. plorans. In E. roseus, five instars in males and six in females (Katiyar, 1961) and Antonion and Hunter-Jones (1968) reported in E.P. ornatipes that male and female both pass through six instars, while in E. P. meridionalis male has six instars and female has seven.

Hodge (1933) reported that an additional instar in acridids is due to different size of male and female grasshoppers. He further reported that there is no correlation of an extra instar with food or sex as in Melanoplus. In Locusta, Kay (1936) assumed that the additional instar is an inherited character, and

temperature or relative humidity has no effect on it. Iqbal and Azis (1974) reported six instars in both males and females of Spathosternum paraseniferum. Majeed and Azis (1975) reported 4 to 6 instars in males and 6 to 7 instars in females of Gastrimargus transversus Thumb. In Trilophidia annulata Moonis and Azis (1977) reported five instars in both the sexes.

In Oxya velox Fab. it has been reported by Rao (1921) that both sexes pass through 6 nymphal instars but rome times an additional moult may be observed in females only.

The longevity of the adult is affected by temperature. Parker (1930) observed that Cannula pellucida survived for only 15.8 days at 37°C and laid 4.2 egg pods per female during this period, where as the life span increased to almost double (36.6 days) at 27°C but only 1.0 egg pod per female was laid. In Chrotogonus trachypterus, Grewal and Atwal (1968) found that female lived longer at 25°C as compared with 30°C and 35°C, but the maximum egg laying was recorded at 30°C. The R.H. had little effect on the reproductive potential. Several studies on the seasonal life history of grasshoppers have been done, notable among them are Rao (1921); Uvarov (1928); Pruthi and Nigam (1939); Shotwell (1941); Richard and Wallof (1954); Aggrawal (1955); Katiyar (1955, 1956); Mac-Carthy (1956); Edward (1960); Pickford (1960, 1966); Riegert and Pickford (1963) and Khan and Azis (1973). The climatic conditionr play an important role in overall fluctuation of grasshopper population. It is also correlated with the

availability of food. Favourable ecological conditions increase biological activities. The detailed information on the seasonal life history of Oxya velox Fab. is not available except a couple of brief notes.

Various workers have studied in detail the behavioural patterns of different insects in relation to temperature, light and humidity. Bodenheimer (1931) found that the humidity in the apparatus did not affect the preferred temperature of the two species of beetles. Savory (1934) found that the spider Zygiella x-notata preferred the wet end at 5°C but the drier end at 20°C, which is the reversal of the humidity reaction. Nicholson (1934) in Lucilia found an increase in the activity with a rise in temperature but did not observe their behaviour against the combinations of temperature and humidity. Key (1936) found that third, fourth and fifth instar hoppers of African Migratory Locust were more active in dry air than in moist air.

The humidity reaction of the cockroach is variable and not so intense. In the identical apparatus Locusta shows a more intense and consistent reaction in the same direction (Kennedy, 1937) and wood lice, a very intense and consistent one in the opposite direction (Gunn, 1937). The time spent in activity is affected by low and high humidity in Locusta (Kennedy, 1937) but this was not so in Schistocerca where the duration of the activity was significantly affected by light in the first instar and by light and temperature in the fourth instar (Aziz, 1957).

Kennedy (1939) came to the conclusion from the field observations that Schistocerca hoppers were active in high light and inactive in dim light. A number of authors (Bodenheimer and others, 1929), working on *L. gregaria*; Parker (1930) on Melanoplus mexicanus (Saus) and Camnula pellucida (Scudd); Hussain (1937) on Locusta, Schistocerca and Nomadacris and Kennedy (1939) on Schistocerca found positive thermokinesis.

Gunn and Cosway (1938) studied the preference of the temperature and humidity in Blatta orientalis and found that it preferred drier conditions, but on desiccation exhibited a tendency to become hygro-positive. Kennedy (1939) found that *L. gregaria* preferred a temperature as high as 40°C. Dakshinamurty (1948) studied the behaviour of Musca domestica to temperature and humidity and found maximum activity at high temperature with low humidity and minimum activity at high temperature with high humidity. Burnett (1951) carried out a detailed study for two years on the behaviour of red locust in solitary phase and correlated the movement with the avoidence of temperature higher than 40°C.

Hussain (1937) and Ellis (1951) found that first instar hoppers of Schistocerca hopp more and march less than the fourth instar hoppers. Everly (1929) in Melanoplus differentialis Thos. and Key (1938) in Locusta found that light stimulated the hopping. Chapman (1954) observed that the movement of Locusta hoppers was restricted below 20°C, but it was not inhibited completely.

On these grounds it seems unlikely that low activity caused by low temperature could prevent photokinetic effects. He also found that Locusta hoppers were more active in light than in dark. Willis and Roth (1958) observed that the preference of wet region by the adults of Tribolium castaneum was reversed to a dry reaction after the insects were given water to drink.

Fraenkel (1929) and Kennedy (1939) found a decrease in positive phototactic effect in Schistocerca above 35°C but latter author found little response. Kennedy (1939) performed some field experiments to show that at high light intensities phototaxis becomes negative. He also found an increase in the activity on sudden cooling. Hussain (1932) carried out experiments to investigate the movement of Schistocerca hoppers and observed a definite descent as temperature of the soil kept rising more rapidly than the air, and hoppers remained on the soil as long as the temperature remained optimum. Chapman (1955) stated that humidity plays a major role in the daily course of behaviour. Aziz (1957) found that hoppers of S. gregaria show a tendency to stay longer in the higher humidity provided that it was not beyond 60-70% R.H. The first instar hoppers hopped and turned less at about 70% R.H. at 30°C while the fourth instar hoppers hopped and turned less at about 60% R.H. Aziz (1961) found an increase in the percentage of time spent "active", speed of walking, hopping and turning activities of the starved first instar hoppers of S. gregaria upto 70% and 80% R.H., but beyond

these levels there activities decreased. The time spent by starved hoppers in both halves was not well marked in the R.H. range 50 - 60% and 40 - 70% which may be restlessness due to starved condition.

Much work has been done on the behaviour of insects in relation with the light. Fraenkel (1929, 1930); Karandikar (1933); Hussein (1937); Kennedy (1939) and Volkonsky (1939) have studied the effect of light on the activity of L. gregaria and obtained positive phototactic and photokinetic responses. Edney (1937) and Cloudsley-Thompson (1953) suggested that behaviour of the locust can be divided into active and inactive phases. Ellis (1951) found that the activity measured as the number of hops per unit time was always lower in the fourth instar hopper of L. gregaria than in the first instar. Dickerson (1963) found that locomotor activity of locusts conditioned to light or dark varied quantitatively but in both period of activity was followed by the resting phase. Nagatomi, Oishi and Tanaka (1967) observed in Oxya yezonensis that the pre-oviposition period and longevity was lengthened under the continuous light, but the number of days between ovipositions was almost the same under both continuous and discontinuous light conditions. The aggregation behaviour among the hoppers of Chromacris colorata was observed by Mathieu (1970). Alcock (1972) observed in Taeniopoda eques (Burmeister) a planned movement from the roosting site to plant shelter with the rise in atmospheric temperature. Michel (1973) found that the light and dark affected the initiation and cessation of flight in L. gregaria

(Norek) reared in isolated or compact groups. Chalial and Singh (1966) made some field observations on the aggregation behaviour of Oxya netidula (Walk) in Punjab. Barring a few, ecologists have not paid much attention towards Oxya velox Fab./

CHAPTER - III

MATERIAL AND METHOD

Stock Breeding:

In order to maintain the stock adult males and females of Oxya velox Fab. along with the nymphal instars were collected in large numbers from Trifolium alexandrinum fields in the months of June, July and August, 1972, from and around Chaharat village (Distt. Aligarh, U.P.). These insects were kept in the wooden cages, each measuring 53 x 40 x 30 cms (Plate 1, Fig. 1). Three sides of the cages were made of wood while the front side was further divided into two parts, the upper and the lower. The upper part was fixed and made of glass, measuring 31 x 31 cm, while the lower part, measuring 31 x 12 cm, formed a wooden window for clearing. The three wooden sides contained the windows fitted with wire gauze. At about 40 cm from the top of the cage, a false floor of wire gauze was provided with six holes each measuring 3.5 cm in diameter. The metallic tubes, each measuring 11 cm in length and 3.00 cm in diameter were filled with moist sterilized sand (9.00 ml distilled water for 100 gm of sand). These tubes were inserted into the holes of the false floor and provided a pseudo-earth for oviposition. The wooden roof was provided with a lid measuring 13 x 13 cm for transferring the insects and food etc.

These cages were kept in the constant temperature room at 30 $\pm$ 1°C temperature and 70 $\pm$ 5 per cent R.H. where 12 hours' light alternated with 12 hours' darkness. Bundles of cut weed Cynodon dactylon, were placed in a beaker (100 ml capacity) with a trace of water. The food was changed twice daily morning and evening.

Plate 1 :

Fig. 1 : Large rearing wooden cage 53 x 40 x 30 cms.

Fig. 2 : Small hopper rearing cage 30 x 30 x 30 cms.

Fig. 3 : Glass jar used for single pair rearing.

Fig. 4 : Metallic tubes with egg pods from large rearing cage placed in a glass jar for incubation.

Fig. 5 : Test tubes of 50 ml and 30 ml capacity used for single hopper rearing.

The egg-pods obtained from the metallic tubes were removed and placed separately in the glass jars (15 x 20 cm), the open ends of the jars were covered with muslin cloth held with rubber band (Plate 1, Fig. 4). These egg-pods were kept moist with distilled water to maintain 12 per cent contact moisture.

The newly hatched hoppers were transferred into small wooden cages, each measuring 30 x 30 x 30 cm (Plate 1, Fig. 2). The two side walls and the roof were fitted with the wire gauze while the floor with rest of the two sides was made of wood. In the centre of the facing wall, a large hole, measuring 12 cm in diameter and fitted with a sleave of muslin cloth, was provided for transferring the insects and food etc. These cages were also placed in the constant temperature room at 30 $\pm$ 1°C and 70 $\pm$ 5 per cent R.H. where 12 hours' light alternated with 12 hours' darkness. Bundles of cut weed Cynodon dactylon were provided for feeding.

In order to study the distinguishing characters, sexual maturity, copulation, oviposition, fecundity, fertility, longevity of the adults, development of the eggs and the hoppers of Oxya velox Fab. the following sets of experiments were conducted:-

(i) Ten pairs of adult males and females were obtained from the stock. The general body colour of these insects was recorded before killing in the Cyanide bottles. Morphometric observations were also made for adults as well as hoppers. These

results are included under the subheading "Distinguishing characters".

(ii) Ten pairs of newly emerged adult males and females were obtained from the stock. Each pair was kept separately in a glass jar measuring 15 x 20 cm. A false floor of perforated zinc sheet or cardboard having a hole 5 cm in diameter in the centre, was provided, at a height of 6 cm from the bottom in each jar. A beaker of 50 ml capacity, filled with moist sterilized sand was inserted in this opening for egg-laying (Plate 1, Fig. 3). The insects were fed on Cynodon dactylon and the food was changed 12 hourly. These jars were then placed in the constant temperature room at 30 ± 1°C and 70 ± 5 per cent R.H. The egg-pods obtained from these jars were placed in small glass jars at the same temperature and humidity.

The number of egg-pods per female was recorded throughout the life of each female. Egg counts were made from each egg-pod. Along with, the observations were also made on copulation, oviposition and longevity of each pair from the same set of experiments.

(iii) Beakers with the egg-pods obtained from the second set of experiments were incubated at 30 ± 1°C and 70 ± 5 per cent R.H. The moisture in the sand was kept constant (8.00 ml of water per 100 gm of sand). The incubation period of the eggs

and the observations on the vermiform larvae were recorded.

(iv) Freshly hatched hoppers were obtained from the stock and reared at 30 ± 1°C temperature and 70 ± 5 per cent R.H. separately in large test tubes of 50 ml capacity (Plate 2, Fig. 3). The conditions of light and food were kept constant. They were fed on Cynodon dactylon. The nymphal duration of male and female hoppers was determined along with the daily rate of development and survival. The results are included in the sub heading "Development of hoppers under the constant ecological conditions".

The observations on the preference of food were made both in the laboratory as well as in the fields. The insects used in the experiments were obtained from the stock maintained in the constant temperature room. Hoppers as well as the adults were fed on a variety of plants throughout the season.

The order of preference of the following food plants was estimated;

1. Triticum aestivum (L.)
2. Zea mays (L.)
3. Oryza sativa (L.)
4. Pennisetum typhoideum (Rich.)
5. Echinocloa colonum (Link.)
6. Setaria verticellata (Beauv.)

7. Cynodon dactylon (L.)
8. Hemarthria compressa
9. Trifolium alexandrinum (L.)
10. Mixed diet of O. sativa, C. dactylon and E. colonum

The experiments were performed at 30 ± 1°C temperature and 70 ± 5 per cent R.H. in the breeding cage (Plate 1, Fig. 1). The cage was provided with 4 holes at the bottom. Four metallic tubes containing cut leaves of different plants with a trace of water were inserted into these holes. The insects were starved for 18-20 hours before releasing into the cage. The food plants were changed; repeated simultaneously and presented in different combinations. The plant leaves eaten at each presentation was recorded at an interval of 5 minutes. Three such observations were made with each set of plant species. After 15 minutes the observations were not recorded as most of the insects stopped feeding. Three replicates with different lots of grass hoppers with the same four plant species at different positions in the cage were done.

The order of preference for each food plant is based upon the differential selection method, where different presentations varied from 30-60 times for each plant species. The results are given in Table-VI where for convenience of comparison they are expressed as the number of times eaten per hundred presentations. The records give a useful guide to the food preferences and are consistent with the field observations. The results of this set of experiments is based upon 50 insects of both sexes at each trial.

(v) 50 freshly hatched hoppers were obtained from the stock and were reared exclusively on a single diet till their survival. Percentage of survival, nymphal duration, maturation period, fecundity and longevity of the adults were recorded. These results are summarised in Tables-VII and VIII.

(vi) 50 adult grasshoppers of both sexes were divided into 5 batches of 10 insects each (5 F + 5 M) and were starved for 18 - 20 hours, then were released into the breading cage with one preferred food plant Cynodon dactylon and one unpreferred plant Pennisetum typhoideum. Water was, however, provided at all times in the petri-dishes with soaked cotton pads. Observation thur made on the manner in which food plants are selected is included in Table-IX.

(vii) In order to study the effect of temperature and moisture on the development of the eggs of O. velox, freshly laid egg-pods were obtained from the second set of experiments. These eggs were divided into batches and incubated at 15°C, 25°C, 30°C, 35°C, 40°C and 45°C with contact moisture levels of 0.0, 8.0, 12.0 and 25.0 per cent. The incubation period and percentage of hatch were recorded and are included in the subheading "Development of the eggs of O. velox in relation to different levels of temperature and humidity".

(viii) Freshly laid eggs were obtained from the second set of experiments and were divided into ten batches and were incubated at 30 ± 1°C temperature with 8.0 per cent, 12.0 per cent and 20.0 per cent contact moisture. The contact moisture was maintained in the following order;

1. 8.0 per cent contact moisture for : 5 days
: 10 days
: Throughout

2. 12.0 per cent contact moisture for : 5 days
: 10 days
: Throughout

3. 12.0 per cent contact moisture for : 5 days
: 10 days
: Throughout

4. 12.0 per cent contact moisture maintained throughout but after 10 days of egg laying.

The R.H. was maintained at 95 ± 5% along with the constant temperature in the C.T. room. Such a humidity level was provided in order to prevent loss of moisture from the sand through evaporation. The incubation period and percentage of hatch were recorded to observe the effect of contact moisture on the development of the eggs. The results are included in Table-XI.

(ix) In order to study the effect of fluctuating temperatures on the development of eggs. Freshly laid eggs were obtained from the second set of experiments and were

divided into six batches. These batches were given two or three exposures of different durations (in days) under the following plan:

1. 15°C for 5 days and then incubated at 40°C temperature.
2. 40°C for 5 days and then incubated at 15°C temperature.
3. 35°C for 10 days, then 5°C for 1 day and then again incubated at 35°C temperature.
4. 15°C for 10 days, then 50°C for 1 day and then again incubated at 15°C temperature.
5. 20°C for 10 days, then 5°C for 3 days and then incubated at 35°C temperature.
6. 35°C for 10 days, then 50°C for 3 days and then incubated at 20°C temperature.

Throughout this set of experiments the contact moisture was maintained at 12% and the R.H. at 75 ± 5% respectively. The results are included in Table-XII.

(x) Freshly hatched hoppers were obtained from the stock and were reared in seven separate batches where each batch contained 50 hoppers. The hoppers were reared at 10°, 15°, 25°, 30°, 35°, 40° and 45°C temperature with 40 ± 5 per cent, 70 ± 5 per cent and 90 ± 5 per cent. relative humidities respectively. One R.H. level was maintained at a time and the experiment was performed in triplicate. The breeding cage described earlier was used and the insects were fed on Cynodon dactylon and 12 hours light alternated with 12 hours darkness. These cages were placed in the constant temperature room. The observations were made on the nymphal duration

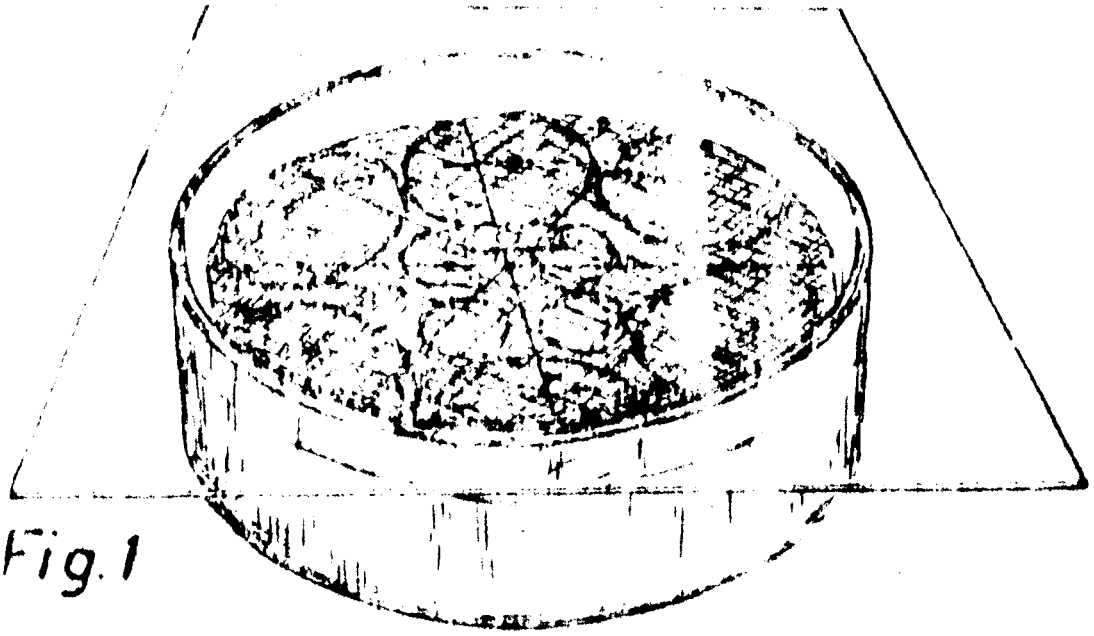

Fig. 1

of both sexes along with the percentage of survival at each instar level. These results are included in, "Development of hoppers of O. velox under different ecological factors" (Table-XIII & XIV).

(xi) Freshly emerged adults were obtained from the stock and were reared in seven batches of 25 pairs each at 10°, 15°, 25°, 30°, 35°, 40° and 45°C temperature with 40 ± 5; 70 ± 5 and 90 ± 5 per cent R.H. separately. The food, Cynadon dactylon was kept constant along with 12 hours alternation of dark and light periods. Each pair was reared separately in glass jars as used in the second set of experiments. These jars were placed in the constant temperature room. The observations were recorded on the survival, fecundity, fertility and the longivity under the different ecological conditions. The results of this set of experiments are included under the sub heading "Development of Adults of O. velox under different ecological conditions" (Table-XV to XVIII).

(xii) In order to study the influence of the physical factors on the reactions of the hoppers of O. velox, the following experiment was designed where the simultaneous influence of two or three physical factors was studied.

An alterantive chamber (Fig. 1) similar to that described by Gunn and Kennedy (1936) was used. The glass trough was 12.5 cm high and 30.5 cm in diameter. Small

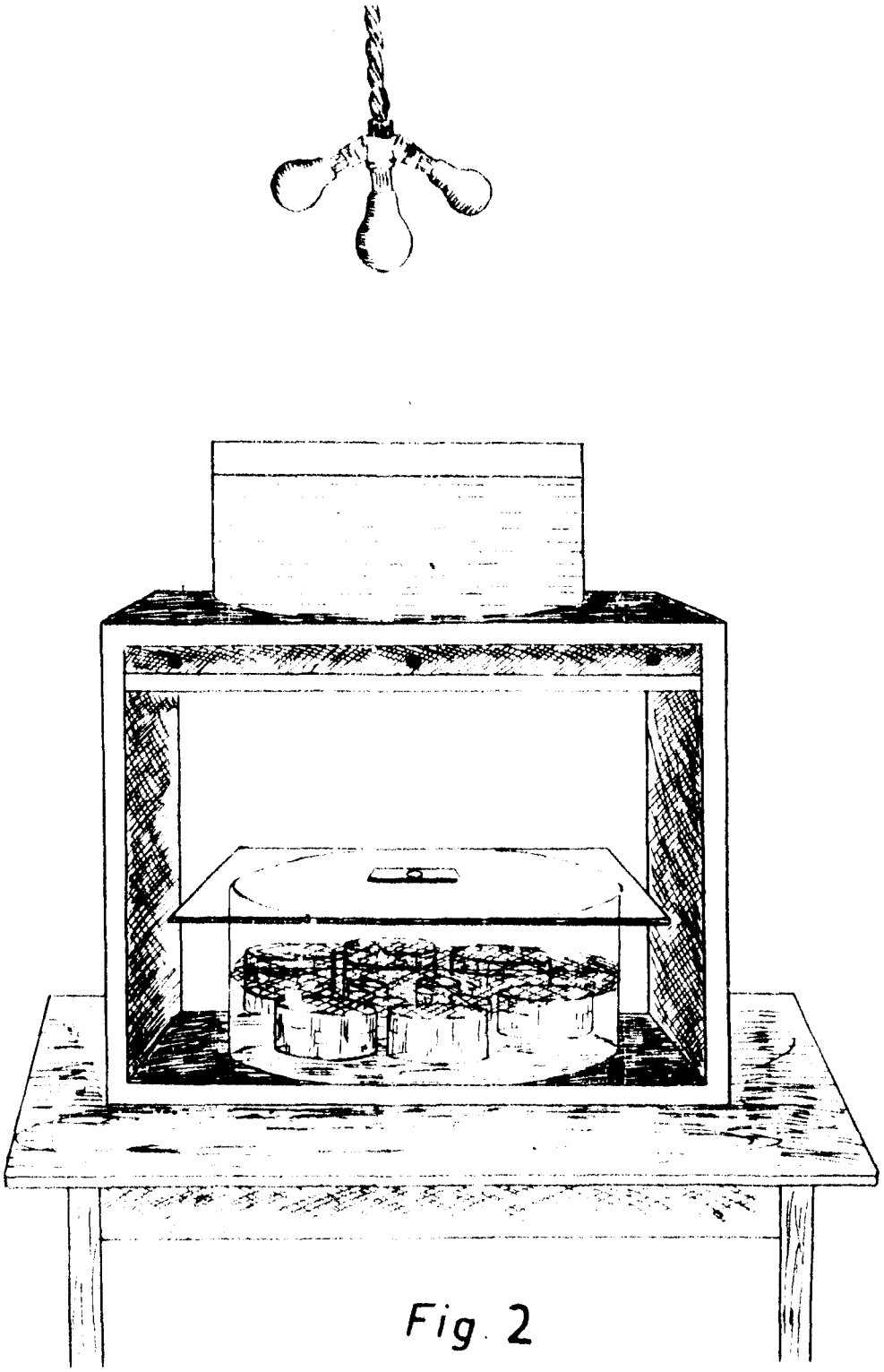

Fig. 2

petridishes were arranged symmetrically so that they covered the whole glass floor and were contiguous along the circumference and the diameter of the chamber. The desired humidities were maintained by means of KOH crystals and water placed in the petridishes. A false-floor of perforated zinc sheet was marked into a number of regions by red lines and was placed over the petridishes. The edges of the false-floor were sealed to the side of glass through with transparent adhesive tape. A glass plate with a central hole covered with a slide, to admit the insects, was placed over the glass trough and made air tight by grease. The alternative chamber was made and kept in the constant temperature room. It takes about 24 hours after the setting of the apparatus to maintain a stationary gradient of humidity extending from about 10 per cent to about 97 per cent R.H. The alternative chamber was placed in wooden box (Fig. 2), about 40 cm square and 32 cm high, having two side walls and a roof made of wood, the latter with a circular opening, 30 cm in diameter, which was covered by a piece of milky plastic sheet. The open back of the box was placed against the wall of the room while the top of the table formed the floor of the box. The front of the box was open to record the observation. A circular glass vessel, 30.5 cm in diameter and 12.5 cm high was filled with cold water and placed over the circular opening of the box. This was arranged to allow the diffused light rays to fall on the false-floor of the alternative chamber and also to eliminate the radiant heat. For the low light intensity (0.7 log foot-lambert), one 60 watt bulb was held with a stand at 30 cm above

the wooden box with glass trough. This was the only light in the otherwise completely dark room. To obtain higher light intensity (2.1 L.F.L.) three bulbs each of 150 watt, were used. The intensity of light on the false-floor was measured with an E.E.I. exposure photometer. This arrangement was used to study the reactions of the hoppers to two physical factors, light and humidity, while the third factor, temperature, was kept constant at 15°C or 30°C in a constant temperature room.

Newly hatched first instar hoppers and newly moulted second, third, fourth, fifth and sixth instar hoppers were obtained regularly from the stock maintained in the laboratory and were preconditioned at 30 ± 1°C and 70 ± 5% R.H. for three days. They were fed twice daily, morning and evening on Cynadon dactylon. The experiments were conducted where the hoppers were provided with a gradient of humidity in the same chamber, the two halves of which are referred to as the "Wet" and the "Dry" halves.

To eliminate the possibility of gregarious behaviour, it was essential to use one hopper at a time. Ten experiments, each of 10 minutes duration were done on hoppers previously conditioned at 30 ± 1°C and 70 ± 5% R.H. for three days. Each insect was released through the central hole of the glass plate which was then covered by a slide. Half an hour was allowed to re-establish the humidity equilibrium. The following observations were then recorded throughout each minute. (1) time spent "inactive" (i.e. complete rest, no movement at all), (2) time

spent "active" (i.e. walking on the false floor), ascending and descending the sides of the chamber or glass plate, movement of legs or body segments and cleaning, etc., (3) the number of hops and turnings made per minute. A turn through 180° was counted as half a turn, while 360° was counted as one complete turn. Although this must be considered to be an imperfect method of recording Klinokinesis, possible factors external to the chamber were eliminated by rotating the chamber through 180° after 5 minutes observations.

In alternative R.H. experiments, special care was taken to record the activities of the hopper and of the time spent in each half of the chamber. The total time spent in the "wet" and "dry" halves was thus recorded. As an estimate of the intensity of reaction, the "excess percentage of reaction" $\frac{W - D}{W + D} \times 100$ was used (Gunn and Conway, 1939). In this expression W and D are the times spent by the hopper in the wet and dry halves, respectively. The theoretical value for no reaction is 0.0 per cent. Intensities of reaction with positive signs denote a preference for high R.H. and vice versa. The results are included in the sub-heading "Behaviour of the hoppers of *C. velox* to light, temperature and humidity". The results are included in Table XIX to XXV.

Besides these sets of experiments, observations were also made on the feeding and roosting behaviour of the hoppers in the laboratory as well as in the fields. Survey of the experimental

field was conducted biweekly for a period of two years from July 1972 to July 1974. The results of all these experiments along with general observations are presented under the respective sub-headings.

CHAPTER - IV

OBSERVATIONS

A. DEVELOPMENT OF OXYA VELOX FAB. UNDER CONSTANT ECOLOGICAL FACTORS:

The following observations are obtained from the first set of experiments:

1. ADULT:

(a) Distinguishing Characters:

In general both males and females are of green colour; medium to small sized with usually elongated cylindrical body having smooth integument. There is a broad black band extending from the upper half of the eye to the base of tegmina; vertex is often with two diverging brown lines and sometimes the middle of the vertex and pronotum is filled up with a brown band. Tegmina is longer than the hind femora, subhyaline in nature with rufous nervures. The costa which is rather expanded near the base, sometimes appears clouded and the inner margin is green. There is no stridulatory mechanism and the tympanum is normally present.

Legs are green in colour, the hind femora with the middle carina terminates in a small tooth. The femoro-tibial joints are marked with blackish and reddish pigmented area. Lower knee-lobe of hind femur is spine like. Hind femora is expanded ventrally. Hind tibiae, beyond the middle, and the first tarsal joints are considerably expanded. The hind tibiae are green with two rows of brown tipped spines on the margins of expanded ventral surface.

Last abdominal sternite in female is bicarinate. The ovipositor valves are serrate. In the newly emerged adults the dorsal band appears whitish green and the rest of the body as bright green, which later on after 4-7 days of emergence turns brown and the bright green colour becomes dull. The prominent pigmentation in this grasshopper diminishes and just a day or two before the death appears almost blackish brown in general. This colour change is more pronounced among the females than the males.

In general the males are slightly smaller in size than the females, but the antennae of males are slightly longer than those of females. The average values of various structures are as follows;

Structures	Male	Female
Body length	2.48 cm	2.73 cm
Antennal length	0.87 cm 28-segmented	0.78 cm 24-segmented
Hind femoral length	1.41 cm	1.50 cm

(b) Copulation;

The following observations are obtained from the second set of experiments;

Both male and female do not start copulation immediately after the emergence and the pre-copulation period varies from three to four days.

To begin with, the male advances towards the female and reaching nearer, touches the female with the antennae while sitting motionless. The male then suddenly jumps and mounts over the back of the female. Often female starts jumping vigorously when it does not want to copulate, thus causing separation, otherwise the male mounts over the back of the female with its fore-legs at the frontal region while the claws grasp the lower margins of pronotal lobes. The middle pair of legs hold the female under its wings above the hind pair of legs, while the hind legs do not take part during the whole process. Hind tibiae are pressed close under the femora and tarsi under the tibiae. After holding the female firmly males abdomen is curved downwards and its tip is brought below the abdomen of female. The aedegus is protruded and inserted between the ventral ovipositor valves. The male cerci clasp the sub-genital plate of the female all the more firmly near its base (Plate 2).

The females with males in copula, may continue to feed, crawl and even jump, when disturbed. The copulation once disrupted may start again after a gap of 17 to 24 hours.

When the copulation is over, the female starts jerking movements and then later on starts jumping with the male, throwing the hind tibiae with jerks. This causes the separation of the two.

Plate 2 : Adults of Oxya velox Fab. showing "Riding type" in copulo.

The act of copulation is completed within two to four hours, and is repeated several times. The females are copulated before or after each oviposition. The frequent copulations are not necessary for successive ovipositions. The first copulation may be sufficient to fertilize the eggs in all succeeding ovipositions. This has been observed in the females kept separately after the first copulation. However, the fecundity is influenced due to the presence of males along with the females. Both polygamy and polyandry are observed as far as the choice of male or female is concerned.

The female at an average copulates 5 to 6 times during the whole life time and the average pre-copulation period is found to be 3.40 ± 0.15 days (Table-I).

(c) Oviposition:

The following observations were made from the second set of experiments:

The average pre-oviposition period is found to be 9.0 ± 0.39 days (Table-I). The moist sand is preferred as a site for oviposition. Often it oviposits on the grass blades provided as food. The egg-batch in the sand is known as egg-pod (Plate 4, Fig. 2) whereas those laid on the grass blades as egg-clutches (Plate 4, Fig. 1).

TABLE - I

Pre-copulation, pre-oviposition, oviposition and post-oviposition period of Oxya velox Fab. reared at 30 ± 1°C temperature and 70 ± 5% R.H. where 12 hours light altered with 12 hours darkness and fed on Cynodon dactylon.

S.No.	Pre-copulation period (days)	Post-copulation period (days)	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)
1.	3	8	11	18	1
2.	4	4	8	9	5
3.	4	4	8	21	6
4.	3	5	8	23	5
5.	3	7	10	15	2
6.	4	4	8	21	6
7.	3	8	11	18	1
8.	3	7	10	15	2
9.	3	5	8	23	5
10.	4	4	8	8	5
Average S.E.	3.40 ± 0.15	5.60 ± 0.51	9.00 ± 0.39	17.10 ± 1.60	3.80 ± 0.61

The female of O. velox, before egg laying, makes a selection of the site by crawling over the surface of the sand along with rhythmic opening and closing of the ovipositor valves, and taps the surface with them. The suitable site is also judged by touching the sand with the help of antennae and palpi.

If the site is found suitable, the abdomen is bent and the ovipositor valves are thrust in closed condition slightly inside the sand and then opened widely. The rhythmic opening and closing of the valves along with gradual backward crawling helps the abdomen to go deeper and deeper. In this way a burrow is made in the sand which is a pre-requisite for egg laying as in all the acridids eggs are laid in the soil. In Oxya velox the burrows are generally 1 to 2.5 cm deep. The depth of the burrow is directly proportional to the extensional capacity of the elastic abdominal intersegmental membranes.

When the burrow reaches the considerable depth, the tip of the abdomen is rotated in a circular way so as to make the walls of the burrow smooth and compact. When the burrow is completed, the abdomen is slightly retracted and the frothy secretion is poured inside the walls which is partly absorbed by the sand and gets hardened. Frothy secretion is also deposited at the bottom of the burrow. The female sits almost motionless with its abdomen bent almost at 90° and hind femora vertical in position (Plate V). Eggs are laid one by one and each one of them is glued with the

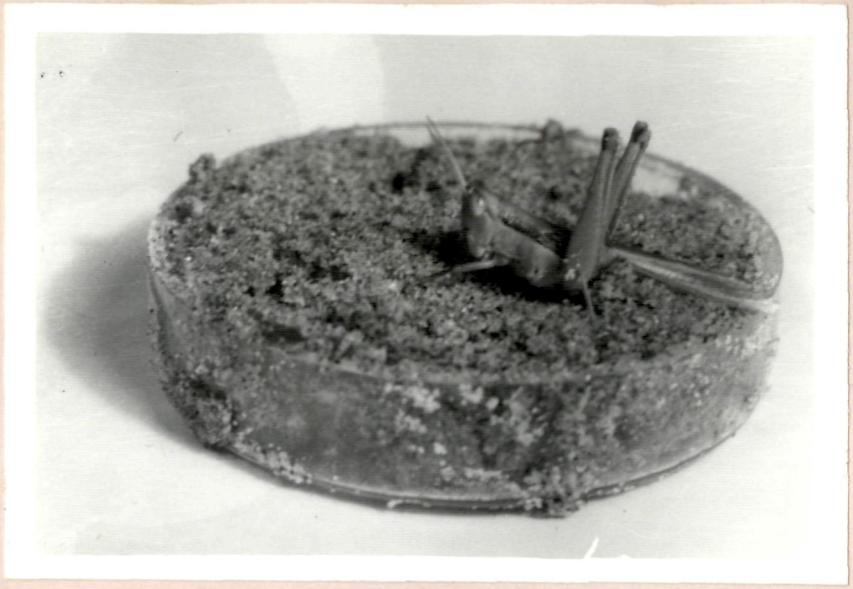

Plate 3 : Female of Oxya velox Fab. in the process of oviposition.

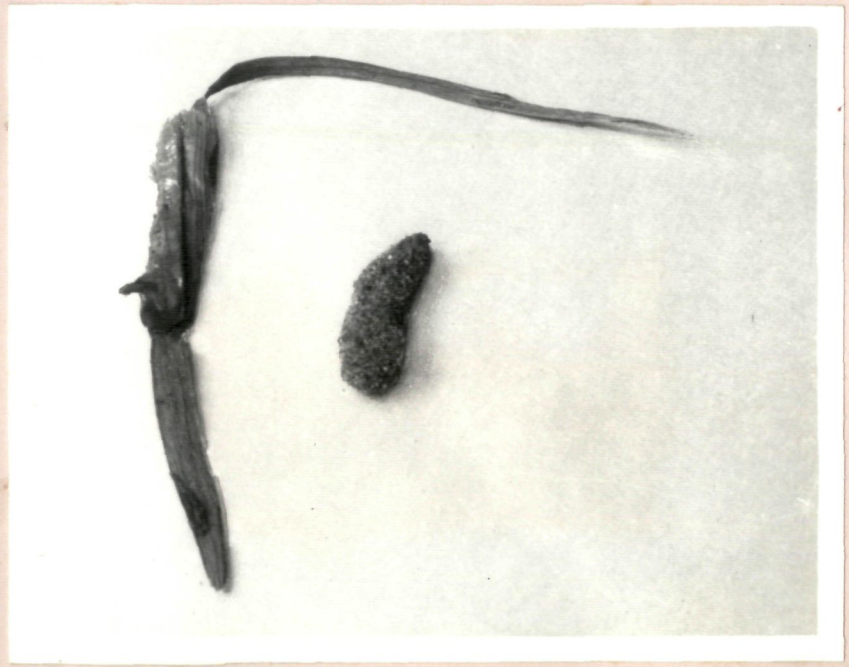

Plate 4 : Egg mass:

Fig. 1 : Egg clutch.

Fig. 2 : Egg pod.

frothy secretion. With the descent of eggs the abdomen is gradually retracted. After the eggs are laid the remaining chamber is filled with the froth. The whole process takes about half an hour to one hour.

The female appears to be exhausted after oviposition as it marches towards the food and starts feeding voraciously.

The average pre-oviposition, oviposition and post-oviposition periods are 9.0 ± 0.39, 17.0 ± 1.00 and 3.8 ± 0.01 days respectively (Table-I).

(d) Longevity of the Adult;

The male has got slightly longer life-span than the female. The life-span of the male at an average is found to be 39.80 ± 1.57 days, while that of the female is 29.90 ± 1.08 days (Table-II).

2. EGG-POD;

The following observations were made from the third set of experiments;

The female of Oxya velox Fab. lays six to fourteen eggs per pod. The number of eggs remain almost the same upto the third oviposition but declines afterwards (Table-III).

TABLE - II

Longevity of the adults of *Oxya velox* Fab. at 30 ± 1°C Temperature and 70 ± 5% R.H. where 12 hours light altered with 12 hours darkness and fed on *Cynodon dactylon*.

S.No.	Male (days)	Female (days)
1.	44	36
2.	41	22
3.	35	35
4.	47	30
5.	39	27
6.	35	35
7.	47	30
8.	39	27
9.	31	36
10.	40	21
Mean ± S.E.	39.80 ± 1.57	29.90 ± 1.68

TABLE - III

Fecundity of the females of *Oxya velox* Feb. at 30 ± 1°C temperature and 70 ± 5% R.H. where 12 hours light altered with 12 hours darkness and fed on *Cynodon dactylon*.

S.No.	Egg pods/ female.	Number of Eggs laid at each oviposition								Total No.of eggs/laid female.	Life span of female (days)
		I	II	III	IV	V	VI	VII	VIII		
1.	5	14	11	11	10	10	X	X	-	56	22
2.	6	12	10	10	9	7	7	X	-	55	35
3.	7	10	10	10	7	7	6	7	-	57	30
4.	7	10	10	8	8	8	6	6	-	56	36
5.	6	12	10	10	9	9	8	-	-	58	27
6.	7	9	9	8	8	8	7	7	-	56	35
7.	6	10	10	10	10	8	8	-	-	57	36
8.	6	11	9	9	11	9	7	-	-	56	30
9.	6	11	10	9	9	8	9	-	-	56	27
10.	6	10	11	11	10	9	6	-	-	57	21
Mean S.E.	6.20 ± 0.18	10.9 ± 0.43	10.00 ± 0.20	9.7 ± 0.34	9.1 ± 0.35	8.30 ± 0.28	7.11 ± 0.31	6.66 ± 0.14	-	56.40 ± 0.25	29.90 ± 1.06

The average number of eggs in each pod is found to be 9.00 (range 6 to 14.0) and the average number of egg-pods per female is 6.20 ± 0.41. The total number of eggs laid by a single female at an average is 56.40 ± 3.92 during the whole life time (Table-III).

The whole compact mass of eggs enclosed inside a frothy secretion secreted by accessory gland is called the egg-pod (Plate 4, Fig. 2). It is dark-brown in colour and is usually cylindrical towards its posterior while the anterior end is pointed. The egg-pod is 1.4 to 3.6 cm long and 0.4 to 0.9 cm in diameter. The basal end of it is usually rounded while it is uniformly thick all along when laid on grass blades. The frothy secretion which glues the eggs is porous and spongy in nature. It gets hardened when dried. The position of eggs in a pod depends on its shape. Internally the pod is usually 2 to 3 chambered. The apex of the pod points upwards while its base is round, with micropylar ends of eggs pointing downwards.

(a) Egg:

The eggs are laid in clusters and are glued together with the frothy secretion. They are mostly placed in two rows with their micropylar ends towards the base of the pod.

The egg is elongated and cylindrical. It is slightly curved and roughly banana shaped (Plate 5). Its broad posterior end tapers slightly towards the anterior end. Freshly laid eggs are

yellow in colour which becomes brown just two or three days before hatching. Freshly laid egg is 0.392 cm long and 0.118 cm in diameter. The size varies slightly among eggs of the same pod, but the shape remains unchanged. The chorion, is thin and densely granulated and the vitelline membrane lies beneath.

The egg gradually increases in size as the embryonic development proceeds. It measures 0.41 x 0132 cm three days before hatching. The chorion becomes thick with pronounced granulation. The micropylar end becomes demarcated. The operculum is distinctly marked with a dark brown circle. The egg as a whole becomes dark brown in colour probably due to the thickening of the chorion.

(b) Hatching:

The eggs of Oryx velox Fab. hatch within 19 to 22 days and the average incubation period is 20.00 ± 0.42 days (Table-IV).

Prior to the hatching black spots appear on the chorion near the operculum. It is at these spots that the chorion eventually ruptures and the vermiform larva hatches out. The vermiform larva purses through the lid of the egg-pod and comes to lie on the surface of sand.

The average percentage of hatching is 99.1 ± 2.30 (Table-IV).

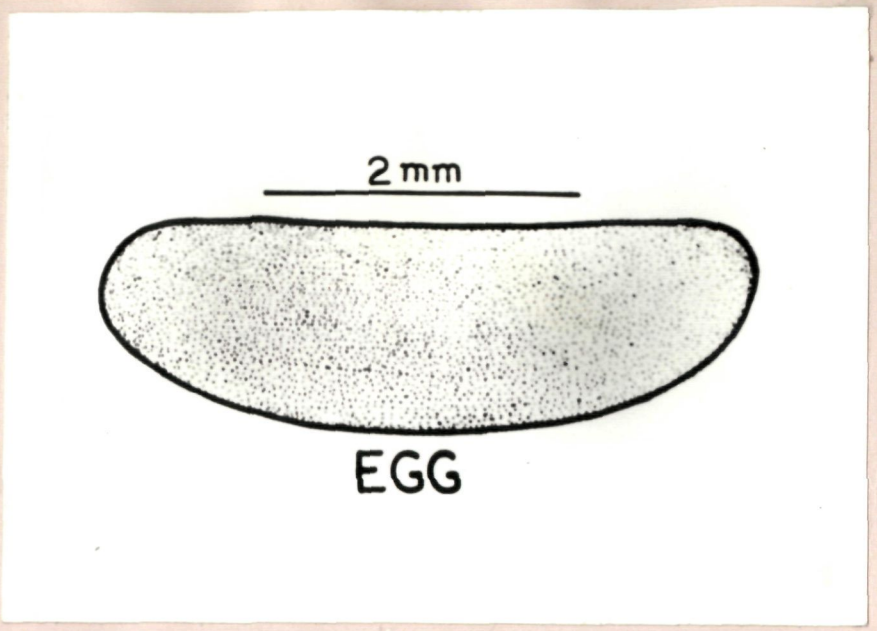

Plate 5 : Egg of Oxya velox Fab.

Plate 6 : Vermiform larva of Oxya velox Fab.

TABLE - IV

Incubation period and percentage of eggs hatched of *Oxya velox* Fab. at 30 ± 1°C temperature and 70 ± 5% R.H.

S.No.	Incubation period (days)	Percentage of eggs hatched	Percentage of egg mortality
1.	22	91.00	09.00
2.	20	100.00	00.00
3.	19	100.00	00.00
4.	21	92.00	08.00
5.	19	91.00	09.00
6.	22	85.00	15.00
7.	19	92.00	08.00
8.	21	90.00	10.00
9.	23	60.00	40.00
10.	20	90.00	10.00
Mean S.E.	20.60 ± 0.42	89.10 ± 2.30	10.90 ± 2.30

(iii) Vermiform Larva:

The vermiform larva remains enclosed in a thick membrane. Its head is bent downwards with the antennae and first two pairs of legs pressed close near the body (Plate 6). The larvae wriggle through the pod and all of them emerge in a group at the opening of the burrow. All the larvae from a single egg-pod emerge in about 10 minutes. The larva casts off its covering membrane after touching the surface of the sand, and this is called as intermediate moult. The alternate contraction and expansion of the cervical ampulla ruptures this white membrane and the young one comes out. The time taken by intermediate moult usually does not exceed more than two to three minutes.

The green coloured vermiform larva measures at an average 0.48 cm in length. Traces of brownish spots are present at the base of setae in fore and middle-legs; hind tibiae are long and posses two rows of spinules. Each antenna is 0.13 cm long and 12-segmented. Width of head is 0.07 cm and the hind femur measures 0.21 cm long and 0.04 cm wide. No traces of wing pads are found, the genitalia appear rudimentary.

(iv) Hopper Instars:

The following observations are obtained from the fourth set of experiments:

The newly emerged hoppers are negatively geotropic and start feeding 4 hours after emergence.

The hoppers undergo six moults before they reach the adult stage. An additional moult may rarely be observed in the females only. The intermediate moult is not included in this count. The duration of the instars vary in the two sexes as well as among the individuals of the same sex (Table-V).

It is also evident from Table-V that the duration of first, second and third instars is slightly longer in the females than the males, while in the fourth and fifth instars it is the other way round. The difference is quite prominent in the last nymphal duration where female takes 11.00 $\pm$ 0.20 days while the male requires 8.80 $\pm$ 0.17 days to become the adult.

The hoppers stop feeding about 4 hours before they undergo moulting and become extremely sluggish. The bright green colour gets faded which may be due to the formation of new cuticle underneath the old one. It takes them 15 minutes to cast off the old cuticle. It has also been observed that proper perching and sufficient space are quite important factors specially for the final moult, whereas the lack of these, results in the deformity, specially of wings.

The female hoppers are slightly larger in size than the male hoppers. The average total nymphal duration in male is

TABLE - V

Duration of hopper instars of Oxya velox Fab. reared at 30 ± 1°C Temperature and 70 ± 5% R.H. fed on Cynodon dactylon and 12 hours light altered with 12 hours darkness.

S.No.	Sex	I instar (days)	II instar (days)	III instar (days)	IV instar (days)	V instar (days)	VI instar (days)	Total nymphal period	Total No.of instars
1.	Male	6	5	6	6	6	9	38	6
2.	"	6	5	6	4	7	9	37	6
3.	"	6	5	6	5	7	8	37	6
4.	"	6	4	7	6	7	9	39	6
5.	"	6	6	5	6	7	9	39	6
Mean S.E.		6.00 ± 0.00	5.00 ± 0.20	6.00 ± 0.20	5.40 ± 0.35	6.80 ± 0.17	8.80 ± 0.17	38.00 ± 0.39	6.00 ± 0.00
1.	Female	7	6	6	5	6	10	40	6
2.	"	7	5	6	6	6	11	41	6
3.	"	7	5	6	5	8	12	43	6
4.	"	6	5	7	5	7	11	41	6
5.	"	6	5	6	5	7	11	40	6
Mean S.E.		6.60 ± 0.21	5.20 ± 0.17	6.20 ± 0.17	5.20 ± 0.17	6.40 ± 0.34	11.00 ± 0.20	41.00 ± 0.48	6.00 ± 0.00

38.00 ± 0.39 days while in female it is 41.00 ± 0.48 days (Table-V).

(a) Description of hopper-instars:

The description of different instars is given below:

First Instar hopper:

Just after the intermediate moult the hopper is called 'hatching'. It is green in colour with a stout conical head having the average width 0.12 cm in both male and female. A broad white band runs from the base of the eyes to the metanotum along the mid-dorsal line. Two dotted pigmented lines run almost parallel to each other along the sides of the band till the last abdominal segment. Minute hairs are present on the cerci and also a row of hairs is present along the mid-ventral line. The hairs form bunches on sixth, seventh and eighth abdominal sternites. Both male and female hoppers are 0.7 cm long. The antenna is filiform, comprises of 12 segments both in male and female and measures 0.15 cm in length. The basal segment is barrel shaped and the second is smaller than the first but the third is as large as or even larger than the first and somewhat conical in shape, the remaining are of uniform shape. The mandibles are of herbivorous type with acute apices.

The fore and middle-legs are small with blackish brown pigmented spots. The hind-pair of legs is stout. Hind-femur is

0.30 cm long 0.06 cm wide and ventrally flattened. Hind tibia is long and ventrally flattened beyond the middle with two rows of brown tipped spinules, one on either side of the expanded furrow; each row has 10 spinules. Tarsi are three jointed, the terminal joint is provided with a pair of claws and median pad.

Wing pads are not distinct in both male and female (Plate 7 & 8, Fig. 1). The abdomen is almost cylindrical. The eleventh tergum and supra-anal plate are fused into one piece with two small cerci on the sides. There are the spendages of the eleventh abdominal segment. The posterior margins of the sub-genital plate in male are semicircularly notched with moderately pointed lobes covering the base of paraprocts (Plate 9, Fig. 1).

In female the lower oviporitor valves are represented by narrow transverse folds separated by a fissure at the base of upper oviporitor valves. The upper oviporitor valves are short, broadly triangular, acute and separated by a V-shaped notch and extend upto the middle of paraprocts (Plate 9, Fig. 7).

Second Instar Hopper:

The second instar hoppers resemble the first instar hoppers in general appearance as well as in colour, except that the broad white band becomes more prominent while the pigmented spots on the front become less prominent.

They are larger in size. The male hopper is 0.9 cm long while the female is slightly larger and measures 0.95 cm in length. The antenna comprises of 15-segments and measures 0.21 cm long in male whereas in female it is 14-segmented and 0.19 cm long. The head width in both male female is 0.15 cm. The hind femur measures 0.48 cm long and 0.1 cm wide in male, while it is 0.5 cm long and 0.1 cm wide in female. The wing-buds are rudimentary, both in males as well as in females (Plate 7 & 8, Fig. 2).

In male the posterior margins of the sub-genital plate are slightly concave, extending upto the middle of paraproctε (Plate 9, Fig. 2). In female the lower ovipositor valves are broadly triangular and separated by a V-shaped notch. The upper ovipositor valves are longer and acute, extending beyond the middle of the paraproctε (Plate 9, Fig. 8).

Third Instar Hopper:

The third instar hopper resembles the second instar hopper in general appearance as well as in colour but it is larger in size. It is 1.2 cm long in male and 1.25 cm in female. Head width in male is 0.1$ cm while in female it is 0.17 cm. The basal segment of the antenna bears pigmented spots. It is 0.25 cm long and 17 segmented in male while in female it is 0.25 cm long and 16-segmented.

The wing buds are stumpy (Plate 7 & 8, Fig. 3). Hind-femur in male measures 0.55 cm long and 0.1 cm wide, while in female it is 0.6 cm long 0.12 cm wide.

In male the posterior margin of the sub-genital plate becomes almost straight to slightly convex (Plate 9, Fig. 3). In female the ovipositor valves do not extend beyond the paraprocts. The lower ovipositor valves do not reach the upper ovipositor valves (Plate 9, Fig. 9).

Fourth Instar Hopper:

The males of first and second instars can be differentiated from the females of the same instars only on the basis of external genitalia. The male inster hopper after the second instar can be differentiated on the basis of smaller size along with the genitalia.

The colour of fourth instar hopper is normally green but some times it is brown. Male measures on an average 1.4 cm long while female is 1.49 cm long. Head width in both male and female is 0.2 cm. The antenna is filiform. It is 0.37 cm long and 21 segmented in male while it is 0.32 cm long and 20 segmented in female. The hind-femur in male measures 0.72 cm long and 0.12 cm wide, whereas in female it is 0.75 cm long and 0.15 cm wide. Wing-buds are more pronounced but the orientation is yet to be completed in both male and female (Plate 7 & 8, Fig. 4).

In male the posterior margin of the sub-genital plate is sharply convex and extends beyond the middle of the paraprocts (Plate 9, Fig. 4). In female the lower ovipositor valves cover the base of the upper ovipositor valves (Plate 9, Fig. 10).

Fifth Instar Hopper:

The fifth instar hopper is much larger in size and whitish green in colour with a very prominent broad white band along the mid-dorsal line starting from the base of the eyes to the last thoracic tergum.

Male is 1.8 cm long while female is 2.00 cm long with the head width 0.19 cm and 0.21 cm respectively. The length of antenna does not vary in male and female except the number of segments. It is 0.5 cm long. 23-segmented in male and 22-segmented in female. Wing-pads are oriented and extend upto the base of the second abdominal segment in males (Plate 7, Fig. 5). The development of wing pads is faster in female and extend upto the base of the third abdominal segment (Plate 8, Fig. 5). The hind-femur is 0.9 cm long in male while it is 1.09 cm long in female.

The sub-genital plate in male becomes infundibuliform and extends beyond the paraprocts (Plate 9, Fig. 5). In female the lower and upper ovipositor valves extend beyond the paraprocts (Plate 9, Fig. 11).

Sixth Instar Hopper:

The hoppers in this stage become whitish green and almost as large as the adults. The male is 2.15 cm long, while female is 2.4 cm long. The width of head in male and female is 0.22 cm and 0.25 cm respectively. The mandibles are of herbivorous type but spices of mandibles do not remain as acute as in early instar hoppers. The antenna measures 0.7 cm in length and 24 segmented in both male and female.

Wing-pads have further developed and in males these extend upto the fourth abdominal segment (Plate 7, Fig. 6), while in female they extend upto the base of the fifth abdominal segment (Plate 8, Fig. 6).

The sub-genital plate in male remains infundibuliform and extends further beyond the paraprocts (Plate 9, Fig. 6). In female, the lower and upper ovipositor valves extend beyond the paraprocts and the tips become chitinised (Plate 9, Fig. 12). This is the last nymphal stage. The hoppers just before moulting stop feeding and rest on the twig. After some time they begin the rhythmic contraction and expansion of the anterior region of the body. Its head is moved forward and backward. The pronotum moves upwards and downwards by the contraction of cervical ampulla and the cuticle is ruptured along the mid-dorsal line above the pronotum. This slit further increases from the testigium upto the wing-pads. Gradually the insect creeps out of the old cuticle.

The head and thorax emerge from the slit. The old cuticle is discarded as the adult emerges. The wing-pads become horizontal and protrude from the sacs. The first two pair of legs are drawn out and the hind pair of legs is drawn out afterwards. The newly emerged adult is called the "Fledgling". During the ecdysis, the insect keeps breathing at a much faster rate so as to maintain the rhythmic contraction and expansion of its body. Just after the emergence, the fore-wings are expanded partially and the hind-wings are folded like a fan. After 20 to 25 minutes the fore-wings get fully expanded. The hind-wings are hyaline and are also stretched after emergence and then slowly folded back to the same position. The insect now rests for a while and then starts feeding.

(c) Key to the female Hoppers:

The following key is applicable to the female hopper instars;

1) Wings oriented; lower and upper ovipositor valves extending beyond the paraprocts; antennae at least 22-segmented. ... 5

Wing-buds stumpy, ovipositor valves do not extend beyond the paraprocts; antennae at the most 20-segmented. ... 2

2) Lower ovipositor valves reaching the upper ovipositor valves; antennae 16-20-segmented. ... 4

Lower ovipositor valves do not reach the upper ovipositor valves; antennae 12-16-segmented. ... 3

3) Lower ovipositor valves represented by narrow transverse folds, separated by a fissure at the base of upper ovipositor valves; upper ovipositor valves short, broadly triangular, acute, separated by a V-shaped notch, extend upto the middle of paraprocts; antennae 12-segmented. ... 1st instar

Lower ovipositor valves broadly triangular, separated by a V-shaped notch; upper ovipositor valves longer, acute, extend beyond the middle of paraprocts; antennae 14-segmented. ... 2nd instar

4) Lower ovipositor valves covering the base of the upper ovipositor valves; antennae 20-segmented. ... 4th instar

Lower ovipositor valves do not cover the base of upper ovipositor valves; antennae 16-segmented. ... 3rd instar

5) Wings not fully developed; outer margins of ovipositor valves not serrate; antennae 22-24-segmented. ... 6

Wings fully developed; outer margins of ovipositor valves serrate; antennae 24-segmented. ... Adult

6) Wing-pads extending upto the base of third abdominal segment; antennae 22-segmented. ... 5th instar

Wing-pads extending upto the base of fifth abdominal segment; antennae 24-segmented. ... 6th instar

B. DEVELOPMENT OF OXYA VELOX FAB. UNDER DIFFERENT LEVELS OF THE ECOLOGICAL FACTORS:

(1) Effect of food plants on the various developmental stages of Oxya velox Fab.:

The following observations were obtained from the 4th, 5th and 6th set of experiments. The results of which are included in Table-VI, Fig. 3.

It is clearly evident that the preference of food changes as the development advances. The early instar hoppers (i.e. 1st to 3rd) show a marked preference to weeds over the cereal crops with as high a survival percentage as 94.00 on Cynodon dactylon. The preference for the cereal crops increases gradually as the development advances except P. typhoideum where it remains very low. Among all the food plants tested T. alexandrinum was the only one which failed to attract the attention of any developmental stage. P. typhoideum is better than the previously mentioned plant, as, a few advanced developmental stages did consume P. typhoideum. The preferential value for the cereal

TABLE - VI

Food preference of hopper instars and adults of *C. velox* Fab. at 30 ± 1°C temperature and 70 ± 5% R.H.
(Based upon the number of times eaten when presented on 100 separate occasions)

Food Plants tested	Ist instar	2nd instar	3rd instar	4th instar	5th instar	6th instar	Adult
1. *Triticum aestivum*	20	20	36	48	50	70	60
2. *Zea mays*	20	20	28	30	48	50	42
3. *Oryza sativa*	30	30	40	70	75	75	90
4. *Pennisetum typhoideum*	-	-	12	20	20	24	20
5. *Echinochloa colonum*	80	80	75	64	56	40	58
6. *Setaria verticillata*	68	65	75	60	52	48	43
7. *Cynodon dactylon*	94	90	95	100	84	78	80
8. *Hemarthria compressa*	80	78	60	52	50	40	50
9. *Trifolium alexandrinum*	-	-	-	-	-	-	-
10. *O. sativa*, *C. dactylon* and *E. colonum* (Mixed)	98	95	98	100	100	100	100

crops is directly proportional to the development where as it is just the reverse for weeds excepting Cynodon dactylon which has fairly stable preferential value throughout. The mixed diet of O. sativa, C. dactylon and E. colonum is highly preferred by the hoppers as well as the adults. The following order of preference is exhibited by adult grass hoppers and arranged in descending order; Mixed diet of O. sativa, C. dactylon and E. colonum; O. sativa; C. dactylon; T. aestivum; E. colonum; H. compressa; L. verticellata; Z. mays and P. typhoideum while T. alexandrinum is not nibbled at all.

More or less the same order of preference is exhibited by the late instar (4th, 5th & 6th) hoppers. Since there is a kind of reversal observed in the preferential values of the early instar (1st, 2nd and 3rd) hoppers, the following arrangement is shown.

The mixed diet of O. sativa, C. dactylon and E. colonum is preferred the most and next in descending orders are; C. dactylon; H. compressa; E. colonum; L. verticellata; O. sativa; T. aestivum and Z. mays where P. typhoideum and T. alexandrinum was hardly nibbled.

Table-VII and Fig. 4 reveals that the survival of the nymphal instars is affected by the food plants. The early instar (1st, 2nd and 3rd) hoppers show a low survival on the cereal crops as compared with the weeds, being as low as 6 per cent on P. typhoideum and as high as 94 per cent on C. dactylon. The late instar (4th, 5th & 6th)

TABLE - VII

Effect of food plants on the survival percentage and nymphal duration of the hoppers of Oxya velox Fab. reared at 30 ± 1°C and 70 ± 5% R.H. where 12 hours light alternated with 12 hours darkness (50 hoppers reared on each diet).

Food Plants tested	Survival percentage of Hoppers		Average Nymphal duration (days)	
	Early instar (1-3)	Late instar (4-9)	Male	Female
P. nestivum	12	50	49.0 ± 1.49*	54.0 ± 1.84*
Z. mays	8	40	53.1 ± 1.05*	58.7 ± 1.07*
O. sativa	16	64	40.5 ± 0.5*	42.0 ± 0.61
P. typhoideum	0	16	59.0 ± 1.51*	67.2 ± 2.22*
E. colonum	54	70	40.0 ± 0.01*	42.0 ± 0.8*
P. verticellata	68	70	39.1 ± 0.73	43.7 ± 0.86*
C. dactylon	94	96	38.0 ± 0.39 (Standard)	41.0 ± 0.49 (Standard)
E. compressa	60	60	48.0 ± 0.02*	53.0 ± 1.79*
T. alexandrinum	All died	-	-	-
Mixed diet O. sativa, C. dactylon, E. colonum	98	98	37.8 ± 0.3	40.1 ± 0.48

* Significant at P = 0.05 or less.

hoppers survived in a greater percentage on the cereal crops as compared with the early hopper instars but in all cases survival is maximum on the mixed diet of O. sativa, C. dactylon and E. colonum.

It is also evident from Table-VII that the total nymphal duration of both males and females is affected significantly by the food plants. There is observed an inverse effect on the nymphal duration in accordance to the preferential value of the food plant. The duration is longest i.e., 59.00 ± 1.54 days for males and 67.20 ± 1.22 days for females when fed on the least preferred plant i.e., P. typhoideum, whereas it is shortest i.e. 37.80 ± 0.39 days for males and 40.1 ± 0.48 days for females when fed on the mixed diet which is the most preferred food.

It is clearly evident from Fig. 5 that the difference between the total nymphal durations of males and females is increased where-ever the food is of low preferential value and vice-versa. When the hoppers are reared on the mixed diet which has highest preferential value, the difference noted between the total nymphal durations of the two sexes is 2.3 days, which is increased to 8.2 days when the food is P. typhoideum which is preferred the least.

The results included in Table-VII also reveal a significant adverse effect on the total nymphal duration among males and females respectively, the less preferred food plants result in the significant prolongation upto 21.2 days in males and 27.1 days in females

(when mixed diet is compared with *P. typhoideum*). The effect seems to be more pronounced among females than in males.

The effect of food plants on the maturation period, fecundity, egg survival and longivity of the adults is evident from Table-VIII.

The maturation period of *O. velox* is shortest i.e., 5.0 ± 0.34 days when reared on the mixed diet which is of the highest preferential value and longest i.e. 13.3 ± 0.80 days on *P. typhoideum* having the lowest preferential value. The less preferred food adversely affects the maturation as well as the fecundity where, the former is prolonged while, latter is reduced. The maximum number of eggs are produced when fed on the mixed diet i.e. 80.7 ± 0.88 which is significantly reduced to 13.30 ± 1.39 on the least preferred food i.e. *P. typhoideum*. Thus it is clearly evident that shortest maturation period with highest number of eggs laid is observed in case of most preferred food plant whereas longest maturation period with least number of eggs laid is observed in case of least preferred food plant.

An unpreferred food plant causes a reduction in the number of eggs laid at each oviposition along with a decrease in the total egg production during the entire reproductive life of the female but there is slight effect on the number of egg-pods deposited by a female unless the preferential value is drastically low as in case of *P. typhoideum*.

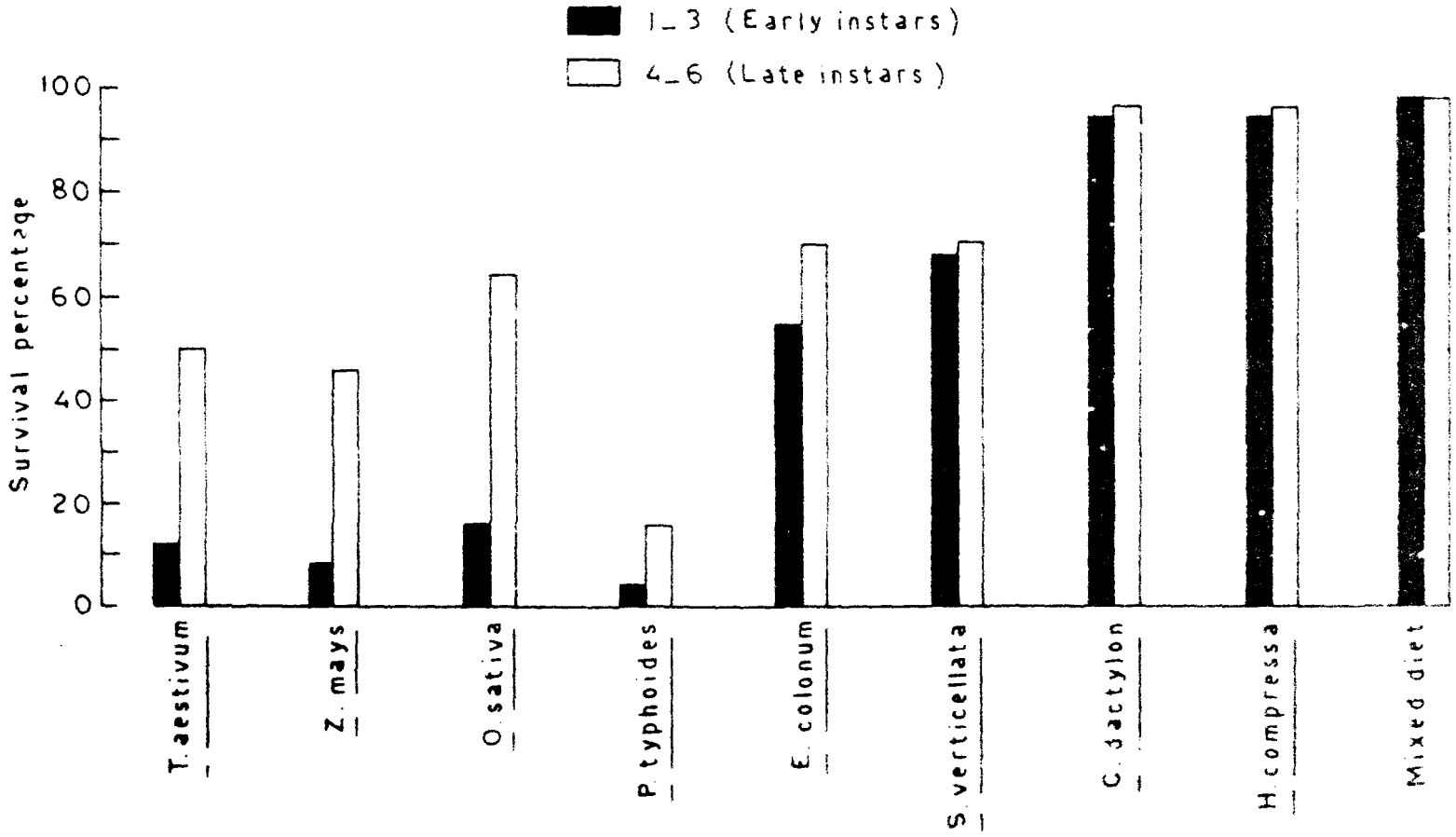

FIG. 5 SURVIVAL OF THE HOPPERS OF Oxya velox Feb. ON DIFFERENT FOOD PLANTS

TABLE - VIII

Effect of food plants on the maturation period, fecundity, fertility and longevity of adults of *Oxya velox* Fab. at 30 ± 1°C and 70 ± 5% R.H. where 12 hours light alternated with 12 hours darkness (Based upon 50 pairs, reared on each diet).

Food Plants tested.	Maturation period (days)	Average No. of egg pods/female	No. of eggs laid/female	Percentage of hatch	Longevity of adults (days)	
					Male	Female
T. aestivum	10.2 ± 0.97	6.80	51.30 ± 0.9*	79.00	42.00 ± 0.26	48.00 ± 1.68*
Z. mays	11.7 ± 0.83*	6.10	40.00 ± 1.54*	40.00	38.00 ± 0.24	43.00 ± 1.54*
O. sativa	7.0 ± 0.68*	7.80	58. 0 ± 1.23	90.00	40.10 ± 0.38	34. 9 ± 0.38*
P. typhoideum	13.3 ± 0.80*	3.20	13.30 ± 1.39	36.30	46.00 ± 0.60*	54.00 ± 1.89*
E. colonum	9.8 ± 0.48	7.10	48. 1 ± 1.21*	62.00	41. 3 ± 1.24	32. 8 ± 0.07
S. verticellata	9.1 ± 0.72	6.00	53. 3 ± 1.33*	68.00	37.00 ± 0.98	31. 1 ± 0.86
C. dactylon	9.0 ± 0.39 (Standard)	6.20	56. 4 ± 0.25 (Standard)	89.10	39. 8 ± 1.57 (Standard)	29. 9 ± 1.68 (Standard)
H. compressa	11.2 ± 0.48*	6.40	41. 2 ± 0.83*	65.00	42.00 ± 1.50	36.00 ± 0.74*
T. alexandrinum	-	-	-	-	-	-
Mixed diet *O. sativa* *C. dactylon* *E. colonum*	5.0 ± 0.34*	8.10	80. 7 ± 0.88*	96.50	38. 6 ± 0.39	30.70 ± 0.48

* significant at P = 0.05 or less.

The production of the viable eggs is also effected by the food plants. As high a survival percentage as 90.5 is observed among the eggs laid by the females which were reared on the most preferred food and as low as 30.00 per cent among the eggs laid by the females fed on the least preferred food plant. The viability of eggs is determined indirectly by the percentage of hatching (Fig. 6).

It is revealed from Table-VIII that the longevity of both males and females is effected significantly by the food plants. The less preferred food has an adverse effect on the longevity as it is increased. The prolongation in the longevity from a most preferred to a least preferred food plant is as much as 6.2 days in males and 24.1 days in females. This effect in terms of prolongation is more pronounced in females as compared with the males. The females survive for a longer period than the males even when the food is an unpreferred one.

Differential selection by O. velox Fab. is well marked and the manner in which the food plants are selected is observed. The methods and materials were similar to the previous tests on the food selection except that only 10 adult grass hoppers were placed in the same cage. These grass hoppers were starved for about 18 hours before the observation were made. Water, however, was provided at all times in petridishes with soaked cotton pads. The two plants selected for the test were (of known preferential value) P. typhoideum and C. dactylon.

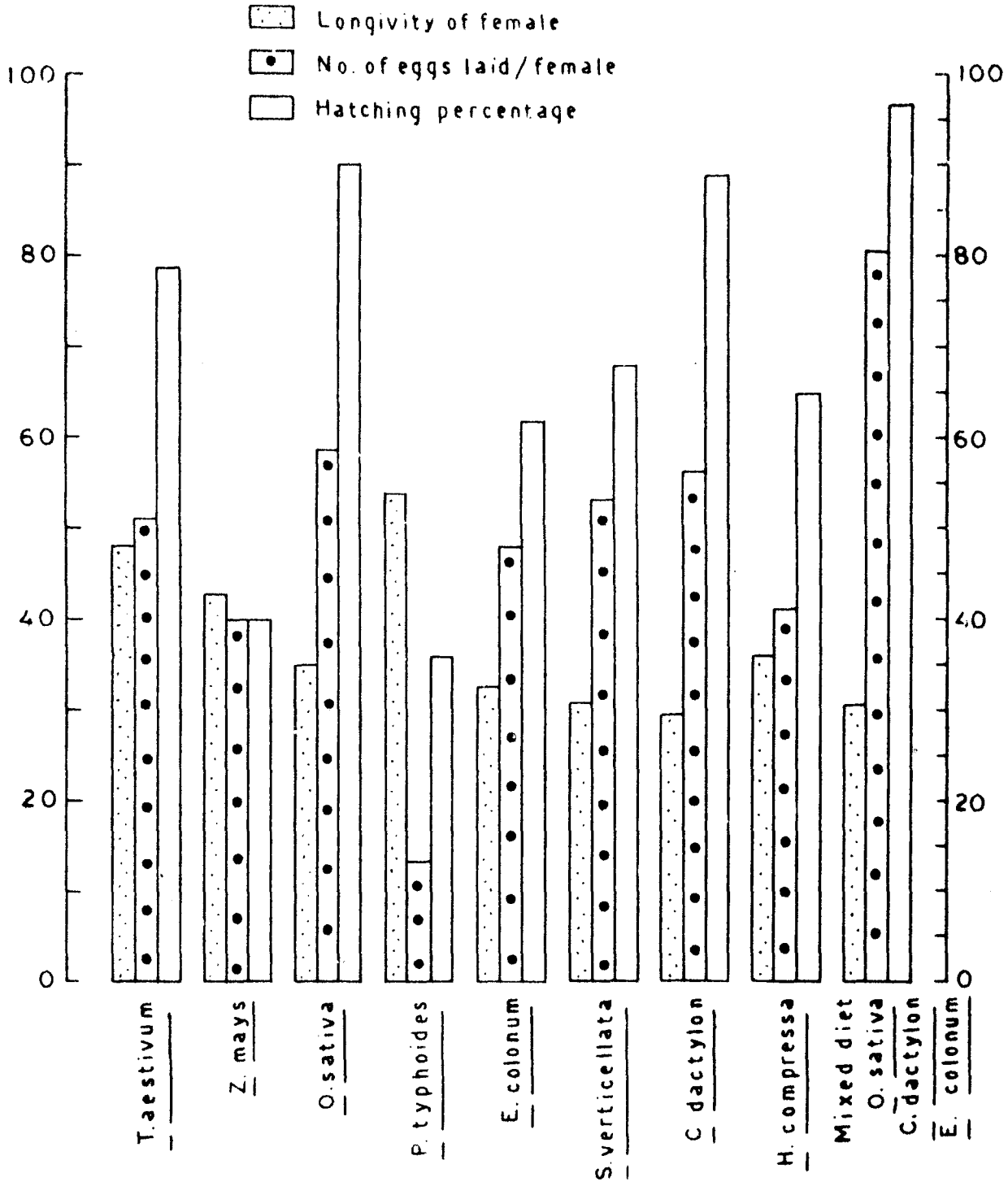

FIG. 6 EFFECT OF FOOD PLANTS ON THE FECUNDITY AND SURVIVAL OF THE EGGS

The grasshoppers were usually located on the sides of the cage at the beginning of the test. When the plants were placed, the grasshoppers began to crawl down the sides and jumped towards the plants. Approximately two minutes passed before the first grasshopper made contact with a food plant. Original contacts were made as frequently with the unpreferred as with the preferred plant (Table-IX). If a grasshopper came in contact with the preferred food C. dactylon it invariably started to feed. After completion of feeding it usually crawled, away from the plant and up one of the sides of the cage.

A different response was observed when a grasshopper came in contact with P. typhoideum, it manipulated the leaves with its maxillary palpi in the same manner as was done for C. dactylon, then it bit the leaf but usually did not feed. It moved about the leaf working its palpi and taking a bite here and there and finally jumped off. Again it took a jump and it seemed that apparently by chance made contact with the adjacent C. dactylon, on which it finally settled and started feeding.

During the process of feeding, an upright position along the edge of the leaf blade was maintained and the margins were consumed along with the apical half of the mid-rib. The grasshopper during feeding moved backwardly towards the base. The tip of any leaf which was neglected initially and fell on the floor of the cage was lateron seen to be consumed by the grasshoppers crawling on the floor. The bundle of cut leaves was almost reduced to a bundle of

TABLE - IX

Observations on adult C. velox Fab. making a selection of food plants when presented with a preferred and an unpreferred food plants.

Exp. No.	Total No. of grass hoppers	No. first contacting with		Transfers		No. feeding	
		C. dactylon	P. typhoideum	P. typhoideum to C. dactylon	C. dactylon to P. typhoideum	C. dactylon	P. typhoideum
1.	10	4	5	4	0	8	1
2.	10	6	2	1	0	7	1
3.	10	5	4	2	1	6	3
4.	10	6	3	3	2	7	2
5.	10	2	8	6	0	8	2
	Average	4.6	4.4	4.0	0.6	7.2	1.8

the lower half of the mid ribs. Some time a grass hopper would feed for a short time on *A. typhoideum* before transferring to *C. dactylon*; less often it left the leaf bundle and crawled up the side of the cage without feeding.

(ii) Development of eggs of *Oxya velox* Fab. in relation to different levels of temperature and humidity:

The following results are obtained from 7th, 8th & 9th set of experiments and are included in Tables-X, XI & XII.

It is clearly evident from Table-X, Figs.7 & 8 that temperature and humidity both have a pronounced effect on the development and the hatching of the eggs. The development is accelerated with a rise in temperature (indicated by decrease in the incubation period). At 35°C with 12% contact moisture it is shortest being 10.00 ± 0.98 days with the highest percentage of egg survival being 91.20 ± 1.09 per cent (indicated by % hatch). Temperature below 35°C results in the prolongation of the incubation period, it is longest at 15°C with 8% contact moisture being 45.40 ± 0.98 days. The effect of humidity is not so marked as that of temperature upto 30°C but beyond that an increase in temperature makes the effect of humidity more prominent. The prolongation caused at 35°C due to 8% contact moisture is more significant than the prolongation at 35°C with 12% contact moisture(when compared with the incubation period at 30°C with 12% contact moisture) Table-X.

TABLE - X

Incubation period and survival percentage of eggs of *O. velox* Fab. kept at different levels of temperature and contact moisture (C.M.) percentage in sand.

Temp. °C	Incubation Period (days)				Percentage of Hatching (Survival) of eggs			
	0.0% C.M.	8.0% C.M.	12.0% C.M.	25.0% C.M.	0.0% C.M.	8.0% C.M.	12.0% C.M.	12.0% C.M.
15°	No hatching	45.40±0.98*	43.20±1.48*	No hatching	No hatching	50.20±1.09*	52.20±0.62*	No hatching
25°	"	29.10±0.04*	26.40±0.83*	"	"	72.20±1.42*	79.10±0.42*	"
30°	"	21.80±1.08	20.60±0.42 (Standard)	"	"	75.30±0.14*	89.10±2.30 (Standard)	"
35°	"	19.20±0.42*	18.60±0.98	"	"	90.40±0.98	91.20±1.09	"
40°	"	15.20±1.12*	16.00±0.12*	"	"	35.80±0.94*	80.40±0.04*	"
45°	"	No hatching	No hatching	"	"	No hatching	No hatching	"

* Significant at P = 0.05 or less

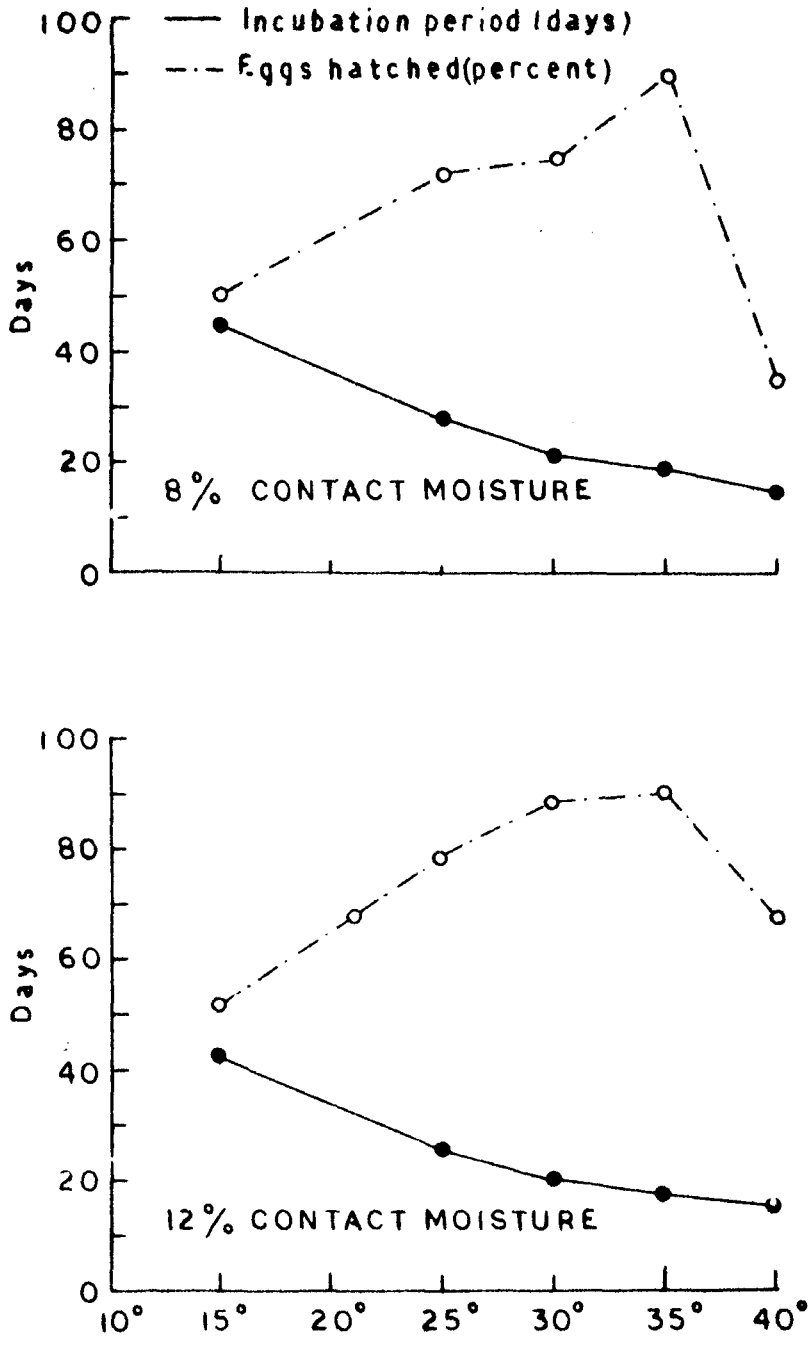

FIG. 7 EFFECT OF TEMPERATURE °C AND MOISTURE ON HATCHING OF THE EGGS

Since the relationship between the temperature and the incubation period is inverse it may be inferred that a rise in temperature accelerates the development of the eggs (Fig. 7). It is also evident from the same table that the extreme conditions of humidity i.e. 0.0 per cent (almost dry) and 45 per cent (almost water logged) are unfavourable for the development of eggs.

Temperature and humidity both affect the survival of the eggs. Too low or too high a temperature adversely affects the percentage of hatching (Fig. 7). The highest percentage of hatching is observed at 35°C being 91.20 ± 1.09 at 12% contact moisture. It is also indicated through Table-X that upto 35°C the effect of humidity alone, on hatching, is not as much as found at 40°C, indicating that as high a temperature as 40°C could not be lethal at 12 per cent contact moisture in comparison to 8 per cent contact moisture. The effect of moisture on hatching is more pronounced than it is on the development.

The effect of contact moisture on the survival of eggs is indicated by Table-XI, Fig. 8. It may be inferred that the water absorbed by the eggs of *O. volox* in the initial stages is sufficient for the completion of development. However, it is not true for all the eggs as the percentage of hatching is maximum at 12 per cent contact moisture maintained throughout. The provision of any one moisture level for 5 days or 10 days does not effect the incubation period as much as the percentage of survival, but there is observed a significant effect due to the moisture levels

TABLE - XI

Effect of contact moisture on the incubation period and percentage of hatching of eggs in *O. velox* fab. at 30 ± 1°C temperature and 95 ± 5% R.H.

S.No.	Period (days) after which eggs were transferred to 95 ± 5% humidity.		Incubation period (days)	Percentage of hatching
1.	8% contact moisture for	5 days	26.10 ± 0.28*	30.00
		10 days	27.00 ± 0.30*	58.00
		throughout	23.20 ± 0.48*	68.00
2.	12% contact moisture for	5 days	21.00 ± 0.84	52.20
		10 days	19.80 ± 0.28	78.80
		throughout	20.60 ± 0.42 (Standard)	90.10
3.	20% contact moisture for	5 days	24.00 ± 0.84*	48.00
		10 days	26.80 ± 0.18*	30.00
		throughout	No hatching	-
4.	12% contact moisture maintained after 10 days of oviposition.		No hatching	-

* Significant at P = 0.05 or less.

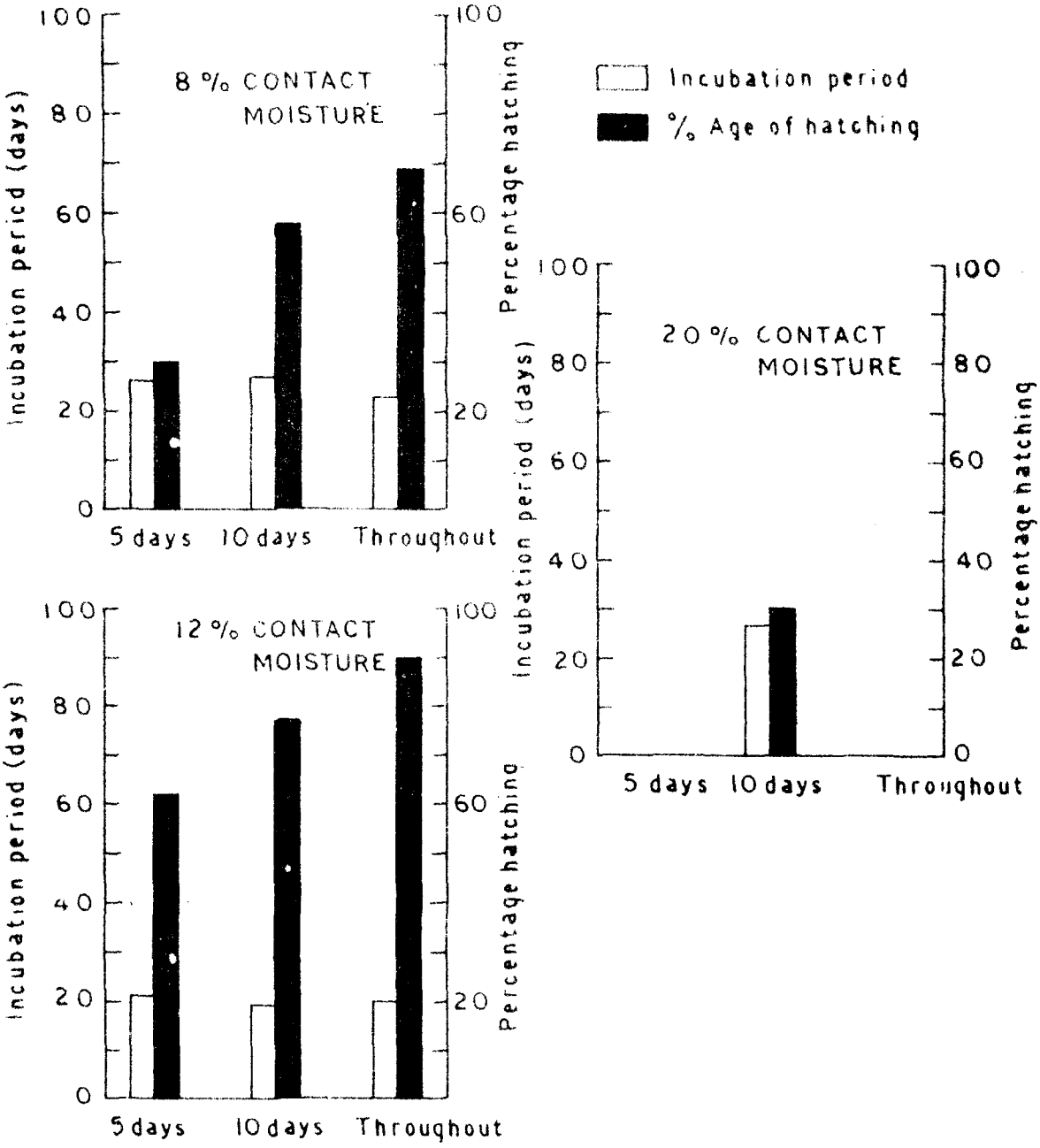

FIG. 8 EFFECT OF CONTACT MOISTURE LEVEL ON THE EGGS OF Oxya velox (Fab.)

(8%, 12% and 25%) on both, the incubation period as well as the percentage of hatching. The survival percentage of eggs is lowest at 8% contact moisture for 5 days; as probably the eggs could not imbibe the required amount of water within this period, and a longer period (10 days or more) is needed. The incubation is shortest (20.00 ± 0.42 days) with highest percentage of survival (90.10 per cent) at 12 per cent contact moisture maintained throughout. The moisture level above or below 12 per cent adversely affects the percentage of hatching.

It is also evident that the availability of moisture, just for the initial crucial period or throughout, effects the percentage of hatching slightly. The period for which the eggs are kept in contact with moisture is important in case of higher or lower moisture levels than 12 per cent.

From Table-XII it is evident that the development is accelarated with a rise in temperature and vice-versa. However, the eggs fail to hatch when exposure of 50°C is prolonged for 3 days. Whereas on the other hand when the same exposure is for 1 day the developmental processes get stimulated, resulting in the reduction of the incubation period. The eggs initially exposed to 15°C for 5 days and then incubated at 40°C completed the development in 2.80 ± 0.48 days, which on comparison with the incubation period at 40°C maintained throughout (Table-X) is significantly prolonged. Just the reverse of it is observed when initial exposure of 40°C for 5 days is changed to 15°C. Here the

TABLE - XII

Effect of fluctuating temperatures on the development of the eggs of *C. velox* Feb. keeping the constant conditions of contact moisture and R.H. at 12% and 75 ± 5% respectively.

I Exposure to fresh eggs		II Exposure		Eggs then incubated at °C	Percentage of hatching	Incubation period (days)
Temp. °C	Duration (days)	Temp. °C	Duration (days)			
15°C	5	-	-	40°C	60.40 ± 0.04*	26.80 ± 0.48*
40°C	5	-	-	15°C	70.20 ± 0.28*	38.10 ± 0.62*
35°C	10	5°C	1	35°C	85.00 ± 0.42	18.40 ± 1.08
15°C	10	50°C	1	15°C	68.00 ± 1.04	28.00 ± 1.68*
20°C	10	5°C	3	35°C	70.00 ± 1.24*	36.20 ± 1.74*
35°C	10	50°C	3	20°C	No hatching	No hatching

* Significant at P = 0.05 or less.

incubation period being 38.10 ± 0.02 days is significantly increased as compared with the incubation period at 15°C from Table-X.

The effect of chilling is more prominent when eggs are exposed to 5°C for 3 days as compared with 5°C for 1 day. The incubation period being 30.20 ± 1.74 days and 18.40 ± 1.06 days respectively.

The fluctuating temperatures affect the incubation period (developmental rate) markedly but the percentage of hatching is reduced in almost all instances of fluctuating temperatures as compared to the ones observed on thore very temperatures maintained throughout as indicated in Table-X. The shortest incubation period and highest percentage survival is observed when exposed at 35°C for 5 days, at 5°C for 1 day and then 35°C for rest of the period. It may be inferred that an exposure to low temperature for a short period accelerates the developmental rate.

The temperature fluctuations affect the incubation period as well as the percentage survival, the effect on the former being more pronounced than the latter.

(iii) Development of the hoppers of O. velox Fab. under different levels of temperature and humidity:

The following observations are obtained from the 10th set

of experiments, the results of which are included in Table XIII and XIV, Figs. 9-12.

It is evident from Table XIII that temperature and humidity both affect the development of nymphs. At 40 ± 5% R.H. (relative humidity) the nymphal duration decreases with a rise in temperature and the survival range of temperature is narrow being 25°C to 35°C. Below or above this range, the nymphs failed to survive. The longest nymphal duration is 46.20 ± 1.20 days for males and 52.40 ± 0.92 days for females at 25°C, which is reduced to 40.00 ± 0.30 days and 42.10 ± 0.42 days for the two sexes respectively. It may be inferred that the rate of development is accelerated with a rise in temperature but it is more prominent from 25°C to 30°C than from 30°C to 35°C. It is also clear that the total nymphal duration of females is affected more than that of males, as the difference between the two is minimised with a rise in temperature.

When the R.H. is increased to 70 ± 5% the survival range of temperature also increases being 10°C to 40°C showing that at high humidity nymphs can withstand as low or as high a temperature which is otherwise fatal at low humidity (40 ± 5% R.H.). The rise in temperature results in the acceleration of the developmental processes. As the longest nymphal duration (50.00 ± 1.24 days for males and 60.20 ± 1.94 days for females) is observed at 10°C, which is reduced to 32.00 ± 0.92 days and 38.00 ± 0.86 days for males and females respectively at 40°C. It is indicated by Fig. 9 that there is a linear relationship between the temperature and the total

nymphal duration. The nymphal duration of both sexes is not affected significantly between 30°C and 35°C but above or below these temperatures there is a significant decrease or increase in the total nymphal duration respectively.

It may be inferred that a decrease in either or both, temperature and relative humidity, results in the prolongation of the total nymphal duration by affecting the rate of development. A high temperature (45°C) is unfavourable irrespective of the humidity conditions.

An increase in R.H. from 70 ± 5% to 90 ± 5% did not affect the nymphal duration of both the sexes within the temperature range of 10°C to 30°C, but beyond this range upto 40°C it is significantly increased among males and females both. It may also be inferred from Fig. 9 that there exists a curved relationship between the temperature and the total nymphal duration of the hoppers only at 90 ± 5% R.H., whereas, it is a linear relationship at lower humidities i.e., 40 ± 5% and 70 ± 5% R.H. The nymphal duration recorded at 30°C is prolonged at 35°C and also at 25°C, but the increase at 35°C is more significant than that of 25°C. Thus showing a pronounced effect of humidity at high temperature(Table-XIII).

It is also revealed through the same table that the nymphal duration of male hoppers is not affected markedly in the range of 10°C to 30°C, but beyond this range it is prolonged significantly. While in the case of female hoppers it is affected above or below the range of 25°C to 30°C. The rate of development is highest at 35°C with 90 ± 5% R.H. being 3.1 and 2.7 for males and females respectively (Figs. 10 & 11).

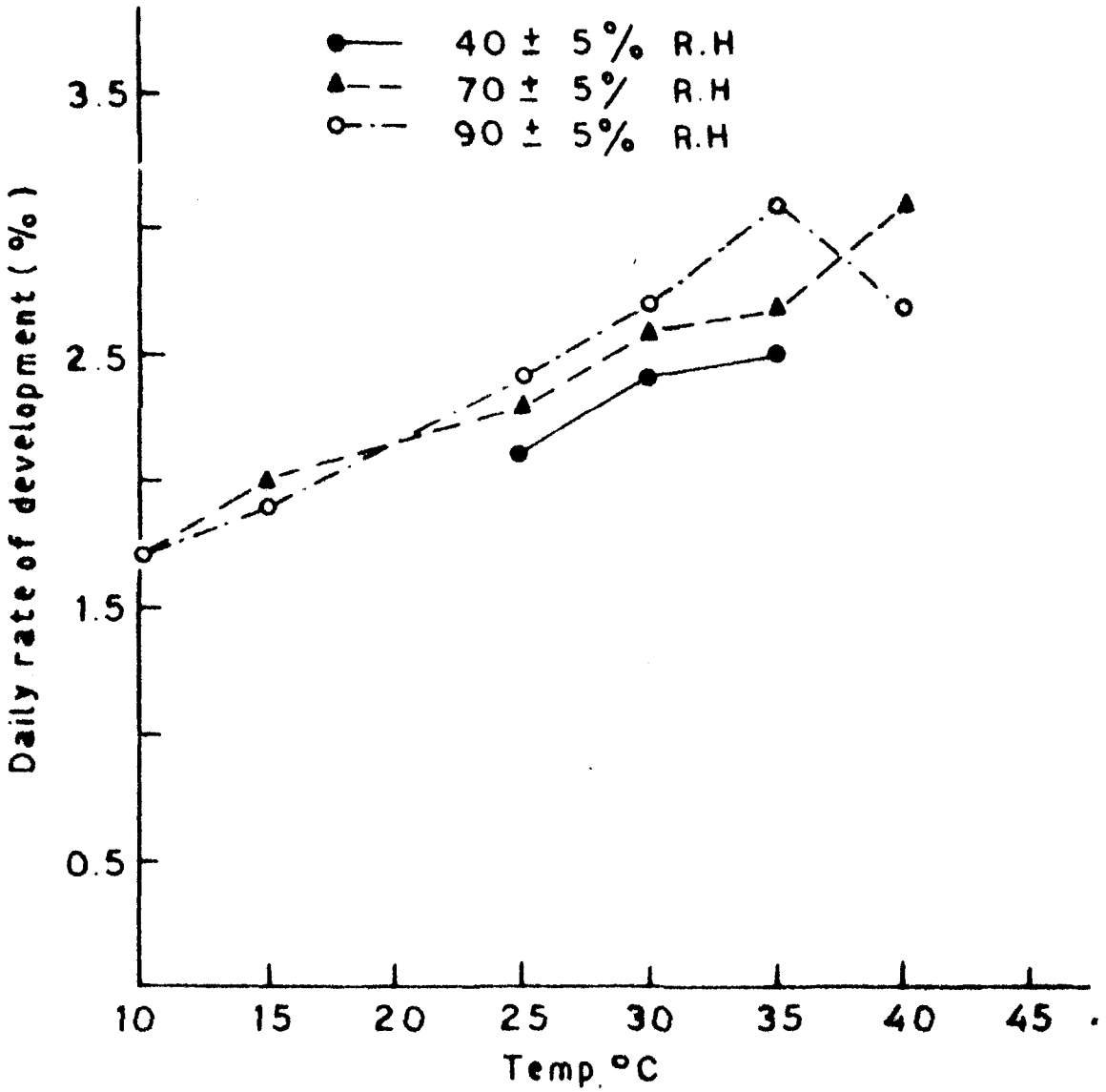

FIG. 10 EFFECT OF TEMP. AND HUMIDITY ON THE DEVELOPMENT RATE OF THE MALE HOPPERS OF Oxya velox FAB

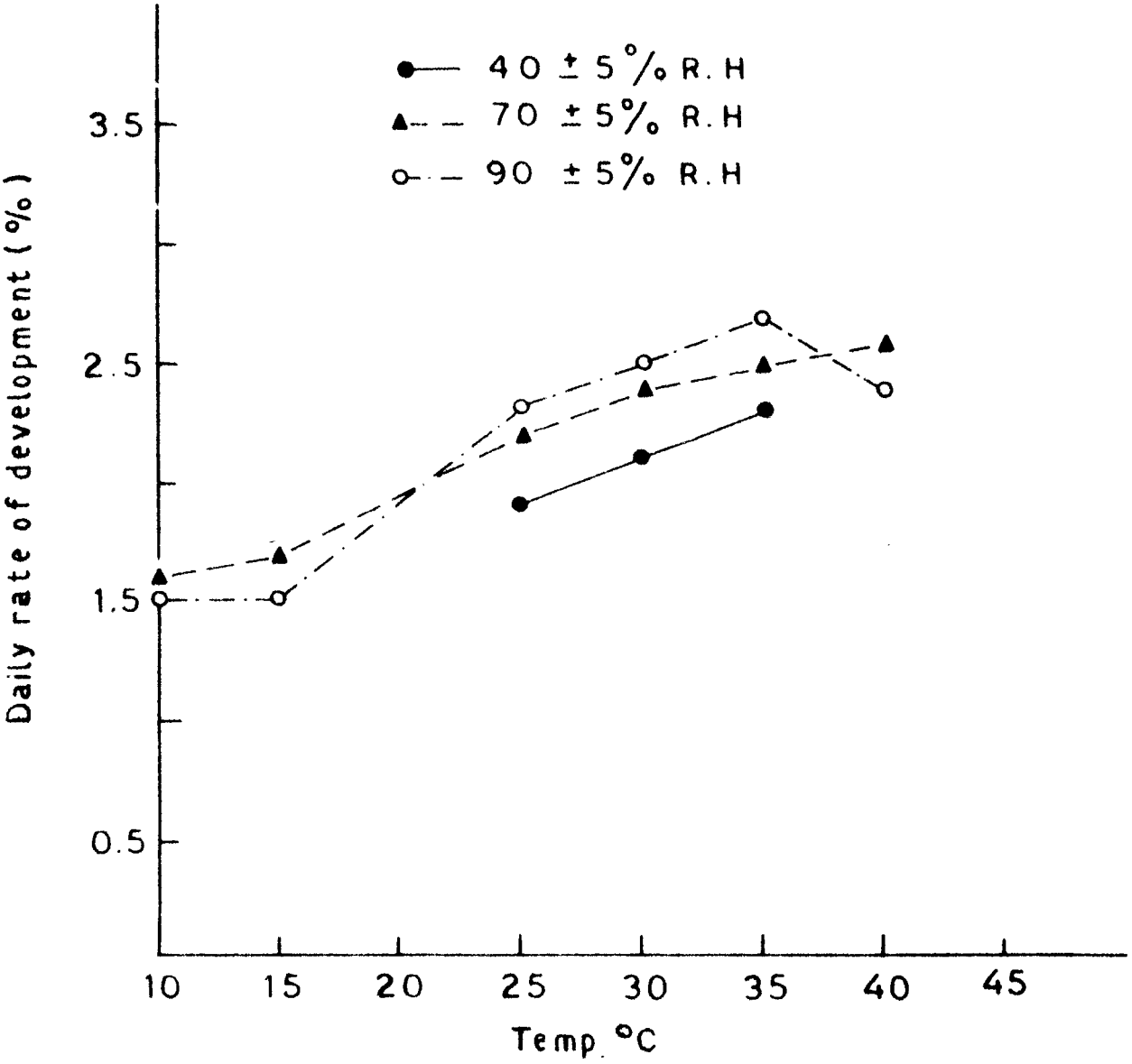

FIG. 11 EFFCT OF TEMP. AND HUMIDITY ON THE DEVELOPMENT RATE OF FEMALE HOPPERS OF Oxya velox FAB.

Temperature and humidity also effect the survival of the nymphs as indicated by Table-XIV, Fig. 12.

At low R.H. (40 ± 5%) the survival range of temperature is from 25°C to 35°C. Below or above this range the nymphs died during the early hopperal stages (1-3), but within this range the percentage survival increased with a rise in temperature. Among females the rise of percentage survival is more obvious as compared with the males.

When the R.H. is 70 ± 5% the survival range of temperature is also increased being 10°C to 40°C, where the maximum survival percentage for both males and females (70.00% and 75.00% respectively) is obtained at 30°C. A rise in temperature upto 30°C increase the percentage survival, where as a further rise causes a decline in percentage. Thus there exists a curved relationship between the temperature and the survival of nymphs. In general the survival percentage among females is greater than the males, which is further increased at highest survival temperature i.e. 40°C.

At 90 ± 5% R.H. the relationship between the temperature and survival of nymphs is almost the same as at 70 ± 5% R.H. but with an increased percentage survival at each level of temperature which is more obviously so when compared with the condition at 40 ± 5% R.H. is obtained at 35°C (being 87.80% for males and 91.20% for females) above or below which it declines.

TABLE - XIV

Effect of Temperature and Humidity on the survival percentage of the hoppers of Oxya velox Fab., fed on Cynodon dactylon, where 12 hours' light alternated with 12 hours' darkness.

Temp. °C	40 ± 5% R.H.		70 ± 5% R.H.		90 ± 5% R.H.	
	Male	Female	Male	Female	Male	Female
10°C	All died in I instar		35.00	38.20	38.00	42.00
15°C	All died upto 4th instar		40.00	48.00	42.20	47.80
25°C	49.10	50.00	55.50	58.00	60.00	68.20
30°C	54.00	58.00	70.00	75.00	78.00	84.00
35°C	58.00	62.00	68.20	72.00	87.80	91.20
40°C	All died		42.20	50.00	50.00	60.00
45°C	All died					

It may be inferred from Table-XIV that at the extreme R.H. condition the survival is largest at 35°C, but the highest percentage (58.00 for males and 62.00 for females) obtained at 40 ± 5% R.H. is increased to 87.80 and 91.20 for males and females respectively at 90 ± 5% R.H.

It is also evident that under humid conditions the survival is more even at the extreme temperatures i.e., 10°C and 40°C.

(iv) Development of adults under different levels of temperature and humidity:

The following observations are obtained from the 11th set of experiments, the results of which are included in Tables-XV, XVI, XVII and XVIII, Figs. 13-17.

It is evident from Table-XV, Fig. 13 that temperature affects both, the maturation and oviposition period significantly as compared with the humidity. There exists a linear relationship between the temperature and the maturation period, the longest being 13.20 ± 0.30 days at 15°C with 40 ± 5% R.H. and the shortest being 3.80 ± 0.34 days at 45°C with 90 ± 5% R.H. A rise in temperature reduces the maturation period. The effect of humidity on maturation is not significant upto 40°C but at 45°C it becomes significant, showing that a high temperature, can well be tolerated provided humidity is high (90 ± 5% R.H.). A rise in temperature to 45°C at 40 ± 5% and 70 ± 5% R.H. affects the maturation adversely.

TABLE - XV

Effect of temperature and humidity on the maturation and oviposition period of the female adults of Oxyvelox Fab. fed on Cynodon dactylon where 12 hours' light alternated with 12 hours' darkness.

Temp. °C	Maturation period (days)			Oviposition period (days)		
	40 ± 5% R.H.	70 ± 5% R.H.	90 ± 5% R.H.	40 ± 5% R.H.	70 ± 5% R.H.	90 ± 5% R.H.
10°C	No oviposition					
15°C	13.20 ± 0.36*	13.00 ± 0.40*	13.90 ± 0.24*	26.20 ± 0.36*	26.00 ± 0.12*	25.80 ± 1.20*
25°C	12.80 ± 0.36*	12.60 ± 0.32*	12.00 ± 0.82*	20.00 ± 0.72	20.10 ± 0.26	19.70 ± 0.30
30°C	9.00 ± 0.42	9.00 ± 0.39 (Standard)	9.10 ± 0.21	17.50 ± 0.29	17.10 ± 1.00 (Standard)	16.00 ± 0.48
35°C	7.00 ± 0.34*	7.20 ± 0.72*	7.40 ± 0.28*	16.80 ± 0.24	16.00 ± 0.02	15.40 ± 0.19
40°C	5.30 ± 0.18*	5.00 ± 0.26*	5.20 ± 0.52*	11.20 ± 0.18*	10.20 ± 0.18*	11.00 ± 0.24*
45°C	No oviposition		3.80 ± 0.34*	No oviposition		7.20 ± 0.16*

* Significant at P = 0.05 or less.

A somewhat similar relationship is exhibited between the oviposition period and the temperature. A high temperature (45°C) with low humidity (40 ± 5% R.H.) adversely affects the oviposition, but it occurs at the same temperature when the humidity is raised to 90 ± 5% R.H. The oviposition period decreases with a rise in temperature, shortest being 7.20 ± 0.16 days at 45°C with 90 ± 5% R.H. and longest being 26.20 ± 0.36 days at 15°C with 40 ± 5% R.H. It is also clear from Table-XV that a rise in temperature from 30°C to 35°C affects the maturation significantly but the affect on oviposition is insignificant.

The fecundity of *C. velox* is affected significantly by both, the temperature and humidity. The effect of temperature being more significant than that of humidity (Table-XVI, Fig. 14). The number of egg-pods deposited per female is increased with a rise in temperature from 15°C to 35°C with R.H. 40 ± 5 (being 3.80 ± 0.21 to 6.20 ± 0.12 respectively), but a further rise in temperature to 40°C affects the number adversely. It may be inferred that too low or too high temperature adversely affects the number of egg-pods laid per female.

A rise in humidity to 70 ± 5 per cent R.H. or 90 ± 5 per cent R.H. increases the number of egg-pods laid. This favourable effect of humidity is more significant at 45°C where the females could oviposit only at 90 ± 5 per cent R.H. It is evident that an increase in humidity from 40 ± 5 per cent to 70 ± 5 per cent affects the number of egg-pods per female more clearly than a rise from

TABLE - XVI

Effect of different levels of temperature and humidity on the fecundity of *Oxya velox* females fed on *Cynodon dactylon* where 12 hours: light alternated 12 hours: darkness.

Temp. °C	Number of egg-pods per female			Total Number of eggs per female		
	40 ± 5% R.H.	70 ± 5% R.H.	90 ± 5% R.H.	40 ± 5% R.H.	70 ± 5% R.H.	90 ± 5% R.H.
10°C	No oviposition					
15°C	3.80 ± 0.21*	4.20 ± 0.18*	4.30 ± 0.19*	15.40 ± 0.91*	18.20 ± 0.9[illegible]*	18.40 ± 1.22*
25°C	5.10 ± 0.22*	5.60 ± 0.17	5.00 ± 0.13*	44.00 ± 1.20*	47.10 ± 1.86*	47.00 ± 1.00*
30°C	5.70 ± 0.2[illegible]	6.20 ± 0.18 (Standard)	6.30 ± 0.28	50.20 ± 1.00*	54.40 ± 0.25 (Standard)	57.40 ± 1.9[illegible]
35°C	6.20 ± 0.12	7.10 ± 0.42*	7.30 ± 0.17*	58.40 ± 1.92	60.00 ± 1.48*	64.80 ± 1.68*
40°C	4.00 ± 0.21*	4.80 ± 0.21*	4.70 ± 0.22*	29.10 ± 1.20*	32.10 ± 1.[illegible]*	32.80 ± 1.6[illegible]*
45°C	No oviposition		2.10 ± 0.12*	No oviposition		12.40 ± 0.86*

* Significant P = 0.05 or less.

70 ± 5% to 90 ± 5% R.H. The increase in temperature from 30°C to 35°C at 40 ± 5% R.H. does not have a significant effect on the number of egg-pods per female, but at higher humidity (70 ± 5% or 90 ± 5%) the effect is significant. There exists a curved relationship between the temperature and the number of egg-pods per female, especially so at 90 ± 5% R.H.

The total number of eggs per female (fecundity) is affected by the change in temperature. It is lowest at 15°C and highest at 35°C, showing an increase with a rise in temperature, but a further increase in temperature to 40°C adversely affects the number of eggs laid by causing a reduction. The effect of an increase in the humidity from 40 ± 5% to 70 ± 5% R.H. is more significant in relation with the total number of eggs, rather than the number of egg-pods per female. High humidity is evidently favourable and more so at high temperature i.e. 40°C and 45°C.

Temperature and humidity not only affect the total oviposition incidences but also the number of eggs laid at each oviposition. It increases upto 35°C with 90 ± 5% where the maximum number of eggs (64.80 ± 1.08) are laid.

Temperature and humidity both affect the longevity of the two sexes of adults (Table-XVII, Fig.15). The survival range of temperature is from 10° to 45°C which is greater than that of nymphs. At 40 ± 5% R.H. the life span suddenly increases with a rise in temperature from, 10°C to 15°C but with a further increase in temperature from 15°C, the life span reduces. Shortest, being 10.10 ± 1.28 days

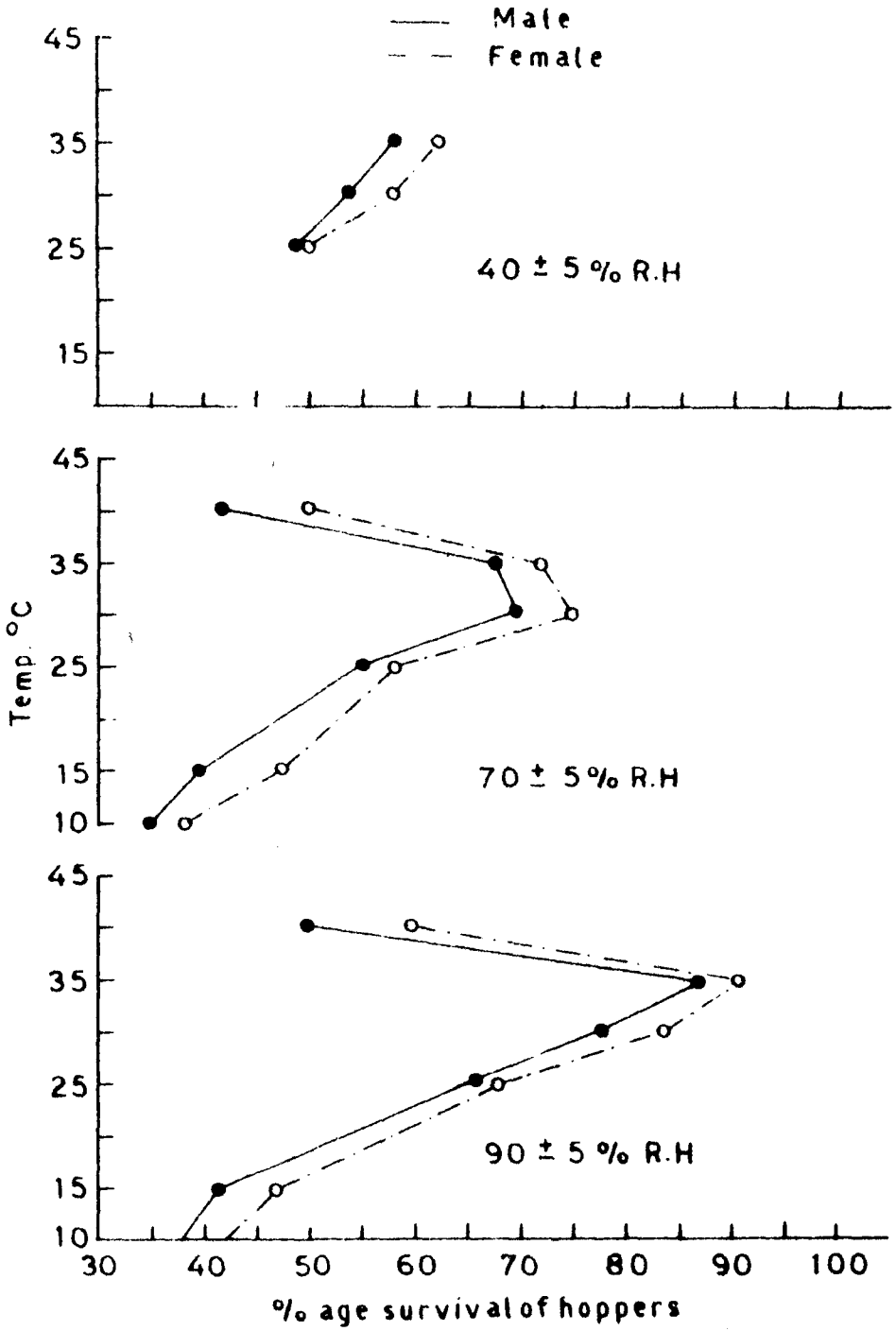

FIG.12 EFFECT OF TEMP. AND HUMIDITY ON THE SURVIVAL OF HOPPERS

TABLE - XVII

Effect of different levels of temperature and humidity on the longevity of the adults of *Oxya velox* Fab. fed on *Cynodon dactylon* where 12 hours' light alternated 12 hours' darkness.

Temp. °C	LIFE SPAN (DAYS)					
	40 ± 5% R.H.		70 ± 5% R.H.		90 ± 5% R.H.	
	Male	Female	Male	Female	Male	Female
10°C	10.10 ± 1.28*	10.80 ± 1.42*	13.70 ± 1.06*	14.20 ± 0.88*	13.90 ± 0.94*	15.00 ± 0.82*
15°C	45.00 ± 1.27*	39.20 ± 1.98*	48.10 ± 0.28*	40.00 ± 1.22*	48.20 ± 1.46*	41.10 ± 1.28*
25°C	43.20 ± 1.90	36.10 ± 1.98*	45.30 ± 1.29*	38.80 ± 1.27	46.10 ± 1.42*	39.00 ± 1.68*
30°C	37.80 ± 1.57	26.90 ± 1.68	39.80 ± 1.57 (Standard)	29.90 ± 1.68 (Standard)	39.90 ± 1.88	29.80 ± 1.75
35°C	36.20 ± 1.28	29.70 ± 1.48	37.80 ± 0.92	29.80 ± 1.28	39.00 ± 0.98	29.80 ± 1.09
40°C	32.10 ± 1.10*	22.40 ± 1.89*	33.00 ± 1.04*	24.10 ± 1.58*	35.70 ± 1.58	27.10 ± 1.12
45°C	28.00 ± 0.98*	24.10 ± 1.21*	32.40 ± 1.72*	28.00 ± 1.91	34.00 ± 1.66*	28.00 ± 1.74

* Significant at P = 0.05 or less.

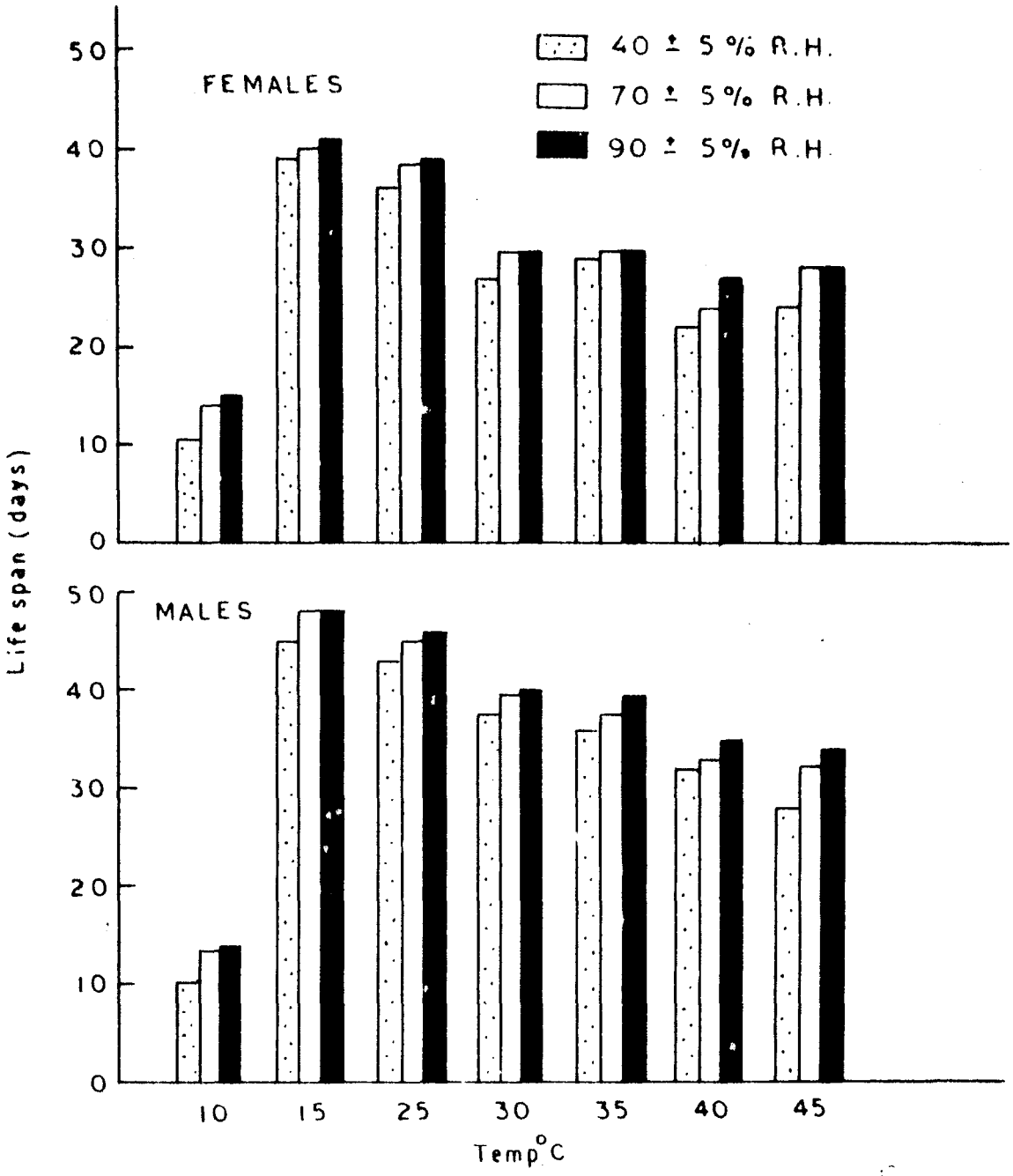

FIG. 15 EFFECT OF TEMP. AND HUMIDITY ON LONGEVITY OF THE ADULTS.

and 10.80 ± 1.42 days and longest being 45.00 ± 1.27 days and 39.20 ± 1.28 days at 15°C, which is again reduced to 28.00 ± 0.98 days and 24.10 ± 1.21 days for males and females respectively. It is evident that at 40 ± 5% R.H. life span decreases with a change in temperature from 15°C. Similar pattern is followed even at higher humidities 70 ± 5% and 90 ± 5% R.H., except that at any one level of temperature life span is increased at higher humidities in both the sexes.

It is also learnt from Table-XVII that there is a difference in the pattern followed by the two sexes. Among males the change of temperature from 15°C (decrease or increase) causes reduction in the life span, whereas among females, the pattern of reduction remaining the same as in males is restricted to 40°C, beyond which i.e., at 45°C the life span increases again.

The difference between the longevity of males reduces at the extreme conditions of temperature but the effect on longevity between 30°C and 35°C is insignificant, irrespective of either the sex or the humidity level. The longevity is greatest for both males and females at 15°C with 90 ± 5% R.H. being 48.20 ± 1.40 days and 41.10 ± 1.28 days respectively. It is also evident from the same Table that at 15°C the males lived longer than the females which is reversed with a change in temperature.

The survival percentage of *O. velox* is also affected by temperature and the humidity, indicated by Table-XVIII. At 40 ± 5% R.H. the survival of males is maximum at 25°C being 76.0% (Fig.16), whereas of females

being 85.00% at 30°C (Fig. 17). Besides these favourable temperatures for the two sexes, the survival percentage is affected adversely with a change in temperature. Thus showing a curved relationship between the temperature and the survival. The percentage survival of females is greater than the males at each level of temperature.

Even at higher humidities (70 ± 5% and 90 ± 5%) the temperature effect establishes a curved relationship between the percentage survival and the temperature (Figs. 16 & 17), along with a greater percentage survival at any one level of temperature. It is also evident that at high humidity (70 ± 5% and 90 ± 5% R.H.) between 25°C to 35°C the percentage survival of males and females is almost equal, above or below which the difference between the two increases along with a decline in percentage survival as well. It shows that below 25°C and above 35°C females survived in a greater number than the males. It may be inferred that in adverse conditions of temperature or humidity, the females are not affected as much as the males. An increase in temperature from 30°C to 35°C and in humidity from 70 ± 5% R.H. to 90 ± 5% R.H. does not significantly effect the percentage survival of either males or females, but both sexes survive in greater number even at extreme conditions of temperature provided humidity is also high.

TABLE - XVIII

Effect of different levels of temperature and humidity on the survival percentage of the adults of Oxya velox Fab. fed on Cynodon dactylon where 12 hours light alternated 12 hours darkness.

Temp. °C	SURVIVAL PERCENTAGE OF ADULTS					
	40 ± 5% R.H.		70 ± 5% R.H.		90 ± 5% R.H.	
	Male	Female	Male	Female	Male	Female
10°C	36.00	40.00	58.00	65.00	59.00	68.00
15°C	40.00	50.00	60.00	65.00	62.00	68.00
25°C	70.00	80.00	86.00	85.00	85.00	85.00
30°C	75.00	85.00	95.00	95.00	95.00	95.00
35°C	70.00	80.00	90.00	95.00	90.00	90.00
40°C	34.00	42.00	50.00	75.00	68.00	78.00
45°C	18.00	28.00	25.00	40.00	30.00	48.00

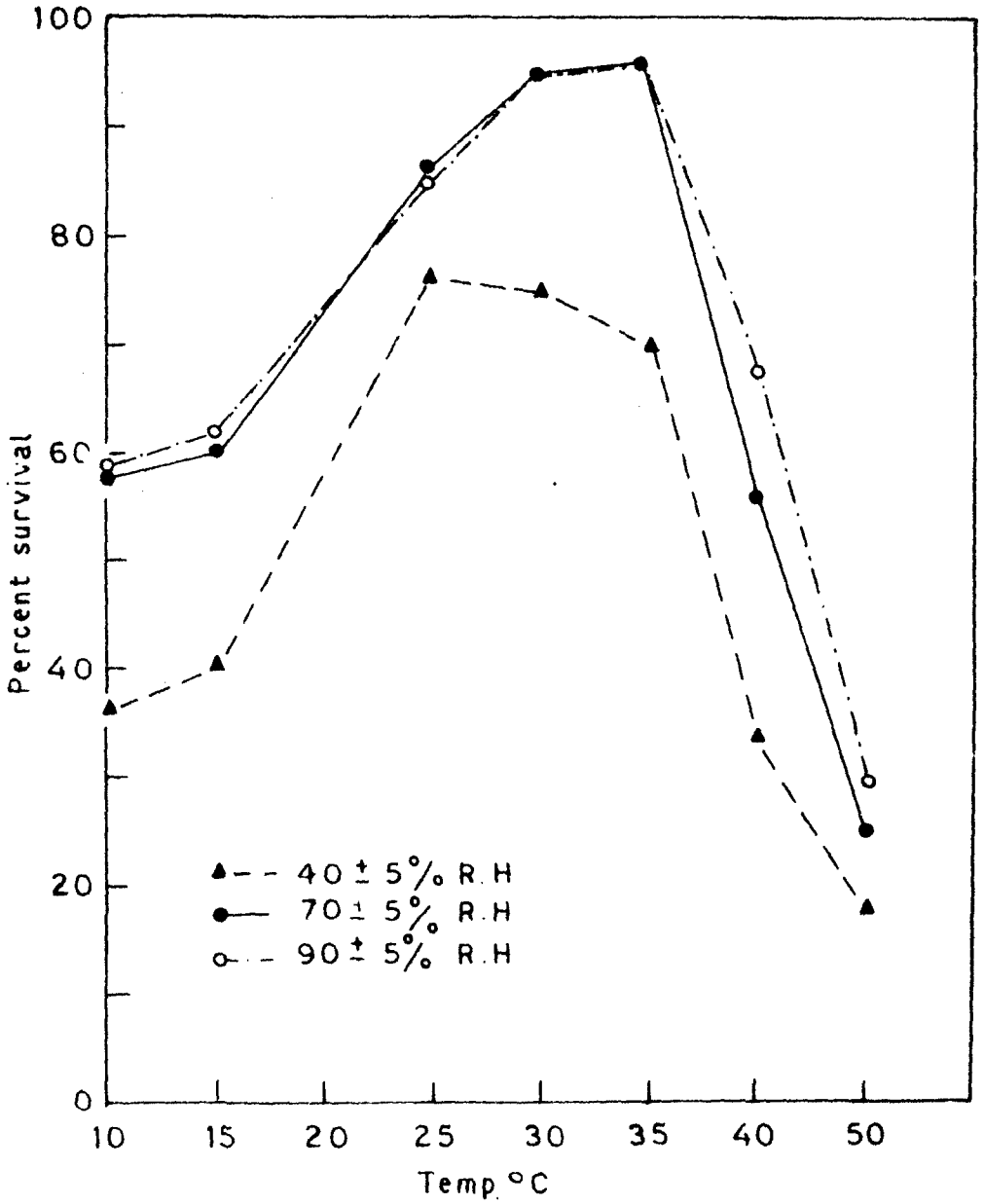

FIG. 16 EFFECT OF TEMP. AND HUMIDITY ON THE SURVIVAL OF ADULTS (MALES) *Oxya velox*

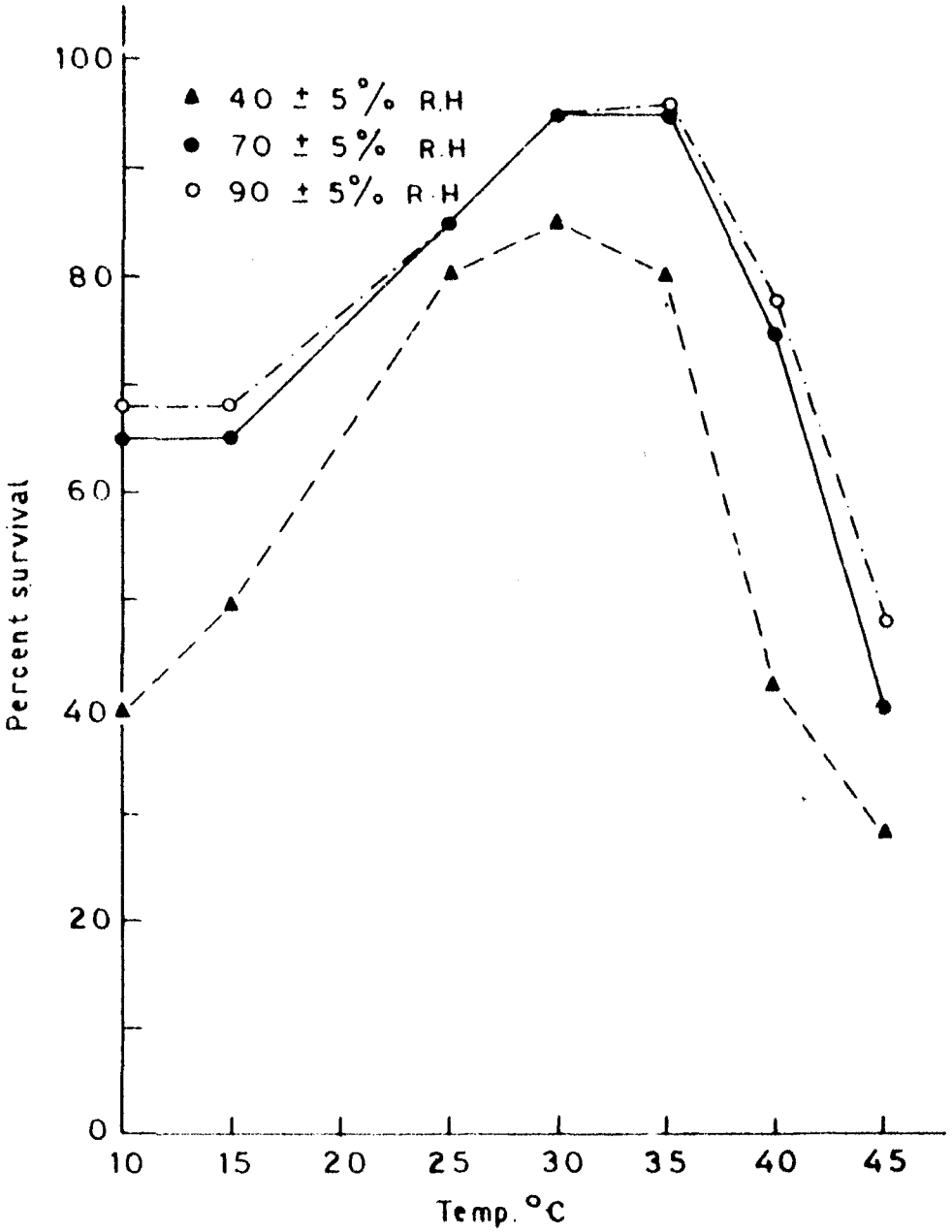

FIG.17 EFFECT OF TEMP. AND HUMIDITY ON *Oxya velox* THE SURVIVAL OF FEMALE (ADULT)

C. BEHAVIOUR OF THE HOPPERS OF OXYA VELOX FAB. TO LIGHT, TEMPERATURE AND HUMIDITY:

The following observations were obtained from the 12th set of experiments.

First instar hoppers:

It is evident from Table-XIX that the first instar hoppers generally prefer to remain in the wet half of the chamber. The difference between the time spent in the two respective halves is more at 30°C than at 15°C irrespective of the light intensity.

At 30°C the preference for the wet half is increased with the rise in light intensity (from 0.7 L.F.L. to 2.1 L.F.L.). On the other hand at 15°C the difference between the time spent in the two respective halves is not so well marked. 15°C coupled with high light intensity (2.1 L.F.L.) resulted in a reversal of the general tendency where hoppers spent more time in the dry half. Since the difference between the time spent in the two respective halves is so small that an actual positive reversal cannot be attributed on the basis of the present observations. This humidity effect is significantly influenced by the rise in temperature. The general activity (hopping turning and movement of body parts) is attributed to irritability due to the unfavourable condition and is more in the dry

TABLE - XIV

Reaction of the first instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 L.F.L. and 2.1 L.F.L.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	49.94	50.06	41.83	58.17	50.10	49.94	38.3	61.7
Percentage of time spent active	41.80	39.53	72.11	52.14	52.00	48.00	80.00	57.83
Ratio between time spent inactive/active	1.39	1.52	00.38	00.91	00.92	1.08	00.25	00.72
Total number of hops	14.00	12.00	26.00	17.00	20.00	17.00	58.00	27.00
Total number of turns	3.00	1.50	0.00	4.75	3.00	1.25	7.25	3.00
Excess percentage of reaction	0.12		16.31		-1.32		23.33	

half than the wet half irrespective of the temperature and the intensity of light, but with in the same light intensity the activity is increased with a rise in temperature. Similarly a comparison of time spent active at 15°C or 30°C with low and high intensity of light reveals that the activity is increased with the rise in light intensity. Thus it may be inferred that both light and temperature affect the activity of the first instar hoppers.

Contrary to it, is the favourable condition where irritability is less and consequently the time spent active is reduced which invariably holds true in the wet half. Inspite of an increase in the time spent active due to a rise in temperature or light intensity, the time spent active is more in the dry half than in the wet half (Table-XIX).

Somewhat similar to this effect is the influence on hopping, which is more in the dry half than in the wet half. Total number of hopps are increased by the rise in temperature but more markedly increased with the rise in light intensity. It may be inferred that the hopping is influenced by light intensity as well as the temperature but is invariably greater in the dry half.

The turning activity (Klinokinesis) is also influenced by temperature. It is clearly evident that turning is more in the dry half than in the wet half and is increased with a rise in temperature in both halves. Unlike other activities, turning seems to have slightly been influenced by the light intensity. It is the temperature and the humidity which influence the turning.

The excess percentage of reaction reveals a well marked preference for wet half specially at high temperature (30°C). The intensity of light also influences the preference where it is increased even further with a rise in light intensity.

It is indicated by analysis of variance (Table-XXV) that the effect of temperature is highly significant.

Second instar hoppers:

The second instar hoppers, like the first instar, tend to remain in the wet half of the chamber, and the difference between the time spent in the two respective halves is clearer as compared to the first instar hoppers (Table-XX). Temperature and light intensity both affect the total time spent in each half. The preference for wet half is greater at 30°C and is further enhanced at high light intensity (2.1 L.F.L.).

The preference for the wet half due to an increase in temperature is greater than that due to an increase in light intensity. At low light intensity (0.7 L.F.L.) a rise in temperature results in a stronger preference for wet half as compared to the similar increase at high light intensity (2.1 L.F.L.). The difference between the time spent in the two respective halves is greater at 0.7 L.F.L. and 30°C. (Table-XX).

TABLE - XX

Reactions of the second instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 and 2.1 log foot lamberts.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	48.33	51.07	28.17	71.83	46.66	53.34	40.00	60.00
Percentage of time spent active	40.00	38.00	69.82	50.11	50.00	42.00	75.00	55.00
Ratio between time spent inactive/active	1.5	1.62	00.28	00.99	1.00	1.38	00.33	00.81
Total number of hops	11.00	9.00	24.00	14.00	18.00	15.00	56.00	25.00
Total number of turns	3.00	2.00	4.50	2.25	2.75	00.75	8.00	3.75
Excess percentage of reaction	3.34		43.66		6.68		20.00	

The time spent active in each half reveals that it is affected by all the three sources i.e. temperature, light intensity and humidity. The activity increased with a rise in temperature and light intensity both, but humidity has an opposite effect, as the activity is reduced in the wet half at both the levels of light and temperature. In general low temperature and low light intensity induces inactivity among the otherwise active hoppers. It is also indicated by Table-XX that hopping is affected similarly as the general activity but it is less established in second instars than the first instars. An increase in humidity decreased the number of hops at the same level of temperature and the light intensity but an increase in either of the two latter sources caused an increase in the hops. Since hyper activity is attributed to the vagueness and irritability due to unfavourable conditions, it may be inferred that high temperature and high light intensity with dry condition is most unfavourable for the hoppers.

The turning activity (Klinokinesis) is almost the same as in the first instar hoppers and is adversely affected by the rise in humidity. The effect of temperature on turning is visible only at 2.1 L.F.L. where it is increased. It may be inferred that the effect of light and temperature is contrary to the effect of humidity

The excess percentage of reaction reveals a well marked preference for the wet half of the chamber. The increase in temperature at 0.7 L.F.L. causes a stronger reaction than the similar increase at 2.1 L.F.L. The effect of temperature is highly significant as shown in Table-XXV (Analysis of variance).

Third instar hoppers:

It is evident from Table-XXI that the third instar hoppers tend to remain in the wet half of the chamber but the intensity of preference is altered in comparison to the previous two stages. The time spent in the wet half is increased either at low temperature with low light intensity or high temperature with high light intensity. The effect of temperature on the time spent active is altered by the change in light intensity (Table-XXI). However, the preference for wet half is greatest at 2.1 L.F.L. with 30°C temperature.

The time spent active is affected by temperature and humidity more than the light intensity. The activity increases with a rise in temperature and the light intensity both, but an increase in humidity adversely affects the activity. Hence the time spent active is least in the wet half at 15°C with 0.7 L.F.L. while it is maximum in the dry half at 30°C and 2.1 L.F.L. light intensity. Low temperature or low light intensity induces inactivity whereas low humidity causes an enhancement, and that is why time spent active in the dry half is always more than that in the wet half (Table-XXI).

The hopping activity is lesser in the third instar hoppers than the previous two stages, but it is affected almost similarly by temperature, humidity and light as observed in the first and second instar hoppers. The number of hops are decreased in the

TABLE - XXI

Reactions of the third instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 and 2.1 L.F.L.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	42.16	57.84	49.16	50.84	49.16	50.84	40.83	59.17
Percentage of time spent active	36.75	32.27	61.96	45.08	45.01	38.03	68.00	52.00
Ratio between time spent inactive/active	1.72	2.09	00.61	1.26	1.22	1.62	00.47	00.92
Total number of hops	10.00	7.00	20.00	10.00	10.00	12.00	28.00	14.00
Total number of turns	3.75	1.50	3.00	1.00	0.25	3.00	6.25	2.50
Excess percentage of reaction	15.68		1.08		1.68		18.34	

wet half at any one temperature but it is increased with a rise in temperature in any of the two halves. The light intensity affects the hopping slightly as it is increased at high light intensity of 2.1 L.F.L. The hoppers are most agitated in the dry half at 30°C with 2.1 L.F.L. (Table-XXI). It is also indicated that this humidity effect on hopping at high temperature is more prominent than at high intensity of light.

The turning activity is almost of the same intensity as in the second instar hoppers, but effect of humidity and light is more prominent among the third instar hoppers. The turning is primarily affected by humidity and then by light intensity but temperature has little or no effect, as indicated by the analysis of variance (Table-XXV).

The excess percentage of reaction reveals a well marked preference for the wet half which is further intensified at the extreme conditions of light and temperature (Table-XXI).

Fourth instar hoppers:

The fourth instar hoppers spend more time in the wet half of the chamber under all the conditions. The preference for the wet half is increased further at high light intensity (Table-XXII).

The time spent active is significantly affected by light, temperature and humidity, where temperature affects it most severely. A rise in temperature or light intensity increase the

TABLE - XXII

Reactions of the fourth instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 and 2.1 L.F.L.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	47.00	52.34	47.00	53.00	45.00	55.00	35.00	65.00
Percentage of time spent active	35.00	30.00	59.75	40.09	45.00	35.00	65.00	50.00
Ratio between time spent inactive/active	1.85	2.32	00.67	1.49	1.22	1.86	00.53	1.00
Total number of hops	8.00	4.00	15.00	8.00	14.00	7.00	18.00	10.00
Total number of turns	3.00	2.5	3.25	1.25	4.00	2.25	6.00	2.00
Excess percentage of reaction	4.68		6.00		10.00		30.00	

activity but, humidity affects it adversely. Hence the time spent active is maximum in the dry half at 30°C and 2.1 L.F.L. while it is minimum in the wet half at 15°C with 0.7 L.F.L. light intensity but even within these two extremes time spent active is always more in the dry half (Table-XXII).

The number of hops among fourth instar hoppers reveals a decline in this activity as the development advances. Hopping is significantly affected by the temperature and humidity both, while the intensity of light does not effect hopping significantly (Table-XXV). Hopping is more in the dry half and is further increased with a rise in temperature. The hoppers are more agitated under dry conditions. It is also indicated by Table-XXII that the humidity effect on hopping is more prominent at 30°C irrespective of the intensity of light but at high light intensity (2.1 L.F.L.). This humidity effect is equally prominent even at 15°C.

The turning activity is significantly affected by the humidity but, the effect of temperature on turning is visible at high light intensity (2.1 L.F.L.) in the dry half only. This activity remains almost unaltered in the wet half of the chamber irrespective of the temperature and the light intensity (Table-XXII). Unlike the third instar hoppers the effect of light intensity on turning is insignificant. The excess percentage of reaction shows a well marked preference for the wet half (Table-XXV). An increase

in temperature, increases the preference for the wet half, which is all the more intensified at high light intensity (2.1 L.F.L.) (Table-XXII). However, in general the discrimination between the two halves is more prominent than observed among the early stages of the hoppers.

Fifth instar hoppers:

It is indicated by Table-XXIII that the preference for the wet half increases with the developmental progress among the hoppers. The tendency to remain more in the wet half is intensified at high light intensity. Where temperature does not affect this tendency at all.

The fifth instar hoppers are less active than the previous stages, yet the time spent active is more in the dry half under all the conditions of light and temperature. The time spent active is increased with a rise in temperature but an increase in the intensity of light has no significant effect. The time spent active is minimum in the wet half at 15°C with 0.7 L.F.L. while it is maximum in the dry half at 30°C with 2.1 L.F.L. light intensity. The effect of an increase in humidity on the time spent active is opposite to that of a rise in temperature where the activity is increased.

The number of hops are further reduced in the fifth instar hoppers but still this activity is greater in the dry half than in the wet half. The effect of light intensity on hopping is prominent

TABLE - XXIII

Reactions of the fifth instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 and 2.1 L.F.L.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	46.67	53.33	46.66	53.34	36.66	63.34	34.16	65.84
Percentage of time spent active	32.14	28.12	60.00	35.93	42.00	32.00	62.00	48.00
Ratio between time spent inactive/active	2.11	2.55	00.66	1.78	1.38	2.12	00.61	1.08
Total number of hops	5.00	2.00	12.00	6.00	9.00	4.00	15.00	8.00
Total number of turns	5.50	3.75	4.25	1.75	5.25	3.00	6.50	3.75
Excess percentage of reaction	6.66		6.68		26.68		31.68	

only at 15°C where it is increased visibly at high light intensity (2.1 L.F.L.). Temperature and humidity both affect the hopping as it is more at high temperature (30°C) and less in the wet half respectively. An increase in temperature and humidity has an almost equal but opposite effect on the number of hops among the fifth instar hoppers (Table-XXIII). The effect of temperature on hopping at low light intensity of 0.7 L.F.L. is more intense than at high light intensity in both the halves (Table-XXIII).

A comparison of the turning activity among the hoppers of different stages reveals that Klinokinesis increases as the development advances. However, this activity is affected mainly by the humidity and hence the number of turns is always greater in the dry half of the chamber (Table-XXIII). An increase in temperature or light intensity does not effect turning significantly (Table-XXV).

The excess percentage of reaction indicates a well marked preference for the wet half which is further intensified at high light intensity (2.1 L.F.L.). An increase in temperature at either of the two light intensities does not effect the excess percentage of reaction significantly (Table-XXIII).

Sixth instar hoppers:

The sixth instar hoppers like the rest, tend to remain in the wet half of the chamber. This tendency is intensified at high light intensity (2.1 L.F.L.). The total time spent in each half is

significantly affected by the intensity of light, whereas temperature has no effect (Table-XXIV).

Sixth instar hoppers are seen less active than the fifth instar hoppers. However, the time spent active is similarly effected by temperature, humidity and light intensity as observed among the fifth instar hoppers. An increase in temperature significantly increases the time spent active whereas the intensity of light affects it at 30°C in the wet half only (Table-XXIV). Time spent active is always more in the dry half irrespective of the temperature or light intensity.

The hopping is least among the sixth instar hoppers, yet it is more in the dry half of the chamber under all conditions. An increase in temperature increases the number of hops, whereas increase in light intensity affects it at 15°C only. The effect of humidity on hopping is just the opposite as it is reduced in the wet half (Table-XXIV).

The turning activity among sixth instar hoppers is most emphatic of all the hoppers and is greater in the dry half. It is primarily affected by the humidity. A rise in temperature at 0.7 L.F.L. increases turning activity more than the similar increase at 2.1 L.F.L. Thus it may be inferred that among the sixth instar hoppers turning is affected by the temperature also (Table-XXIV).

TABLE - XXIV

Reactions of the fixth instar hoppers of Oxya velox in the alternative humidity experiments at 15°C and 30°C with light intensities of 0.7 and 2.1 L.F.L.

	0.7 L.F.L.				2.1 L.F.L.			
	15°C		30°C		15°C		30°C	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Percentage of time spent in each half	49.17	50.83	48.34	51.66	35.00	65.00	36.66	63.34
Percentage of time spent active	29.83	25.08	56.45	32.77	40.00	30.00	60.00	68.15
Ratio between time spent inactive/active	2.35	2.99	00.77	2.05	1.50	2.33	00.66	00.46
Total number of hops	4.00	1.00	7.00	4.00	0.00	2.00	10.00	5.00
Total number of turns	3.75	2.50	8.00	3.00	5.50	2.75	7.00	2.75
Excess percentage of reaction	1.66		3.32		30.00		2.68	

The excess percentage of reaction reveals that the preference for the wet half increases with a rise in temperature as well as that of light intensity. The preference for wet half is intensified where high temperature is coupled with high light intensity.

The analysis of variance (Table-XXV) indicated that temperature and humidity affect the activity in all the stages whereas the effect of light intensity is more visible among the later stages of hoppers.

D. FIELD OBSERVATIONS:

A survey was conducted for a period of two years from June 1972 to June 1974 in order to determine the seasonal fluctuation in the population of *O. velox*, its host range and the behaviour of its hoppers. The area of the survey was Cheberat village in Aligarh district. Samples for this survey were taken at weekly intervals by sweeping the random area of the field for 30 minutes. Findings of this survey are summarised below:

(1) Copulation:

Copulation was observed in the field about 13.00 hrs on September 18th. The preliminaries of copulation were not observed in the field and have already been described from cages. Rest of the process was watched in the field, from mounting to

TABLE - XXV

The analysis of variance of the reactions observed among the hoppers (first to sixth) of Oxya velox Fab.

FACTORS	TIME SPENT ACTIVE						HOPPING						TURNING					
	Hopper instars						Hopper instars						Hopper instars					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Light	+	+	-	+	-	+	+	+	+	-	+	+	-	-	-	-	-	-
Temperature	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+
Humidity	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+
Light & Temperature	-	-	-	-	+	+	+	+	+	-	+	+	-	-	-	-	-	-
Light & Humidity	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Temperature and Humidity.	-	-	+	-	-	+	+	+	+	+	+	+	-	-	-	+	+	+
Light, Temperature and Humidity.	-	-	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	+

+ = Significant at P = 0.05 or less

to separation four times and the last part of the process more frequently. The procedure is very similar to that described in other species of Acridids and they adopt the "Riding type" as described by Katiyar (1952). The following is of interest;

(a) There is a considerable period upto one hour during which the male is mounted but not coupled.

(b) The act of copulation is completed within 30 minutes to 1 hour.

(c) The female continues with her normal activities of feeding, cleaning, defaecating, walking, jumping etc. while in copula.

(d) Both sexes are extremely wary and may be scared by the scratching sound at well over two yards distance. It is only for a short time that the two are firmly joined. Before this the male readily retracts the abdomen, and if the danger approaches closer, both would jump up explosively and fly off in different directions.

Throughout the entire survey, oviposition was never observed in the field but has already been described from the cages. However, rarely an egg cluster was located along the stem of Cynodon dactylon in the axial region specially of the broad leaf.

Similarly the emergence of the hoppers was never observed in the field. However, it was found that very young hoppers tended to cluster together at the tips of the grass blades but this habit did not persist without exceptions. The newly hatched hoppers were found in the short grass patches (unwater logged) or around the raised boundary of the field with the common weed Cynodon dactylon. This distribution of very young hoppers was maintained almost

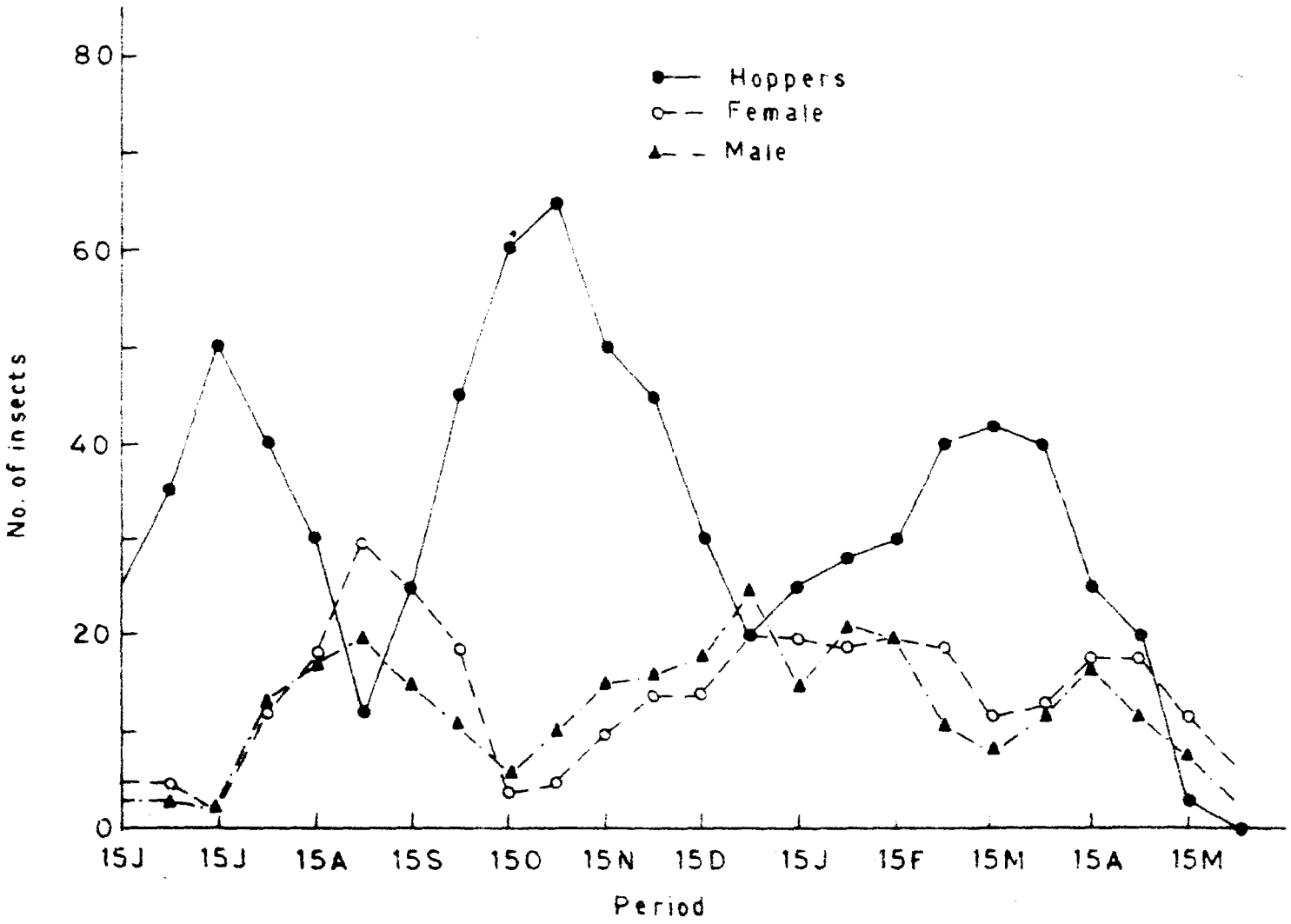

FIG. 18 SEASONAL FLUCTUATIONS IN THE POPULATION 1972 - 73

unchanged during the first two instars. By the time most of the hoppers were in their fourth instar, most of them had moved into the tall grass. In the early stages this was probably due in part, atleast to the initial cohesion of the group from each egg-pod. Assuming so, the site of oviposition in the field could be indicated.

(ii) Seasonal Abundance:

In the first year of survey the sample collected during the middle of June (15th June 1972) yielded only a few adults all of which were of advanced age-effect determined by the colouration of the body which is found to become darker among the old adults.

Hatching in the field apparently started before the date of the first collection and reached its peak within a month's period so that the sample collected in the middle of July was having a large number of hoppers in it (Fig. 18), showing that the hopper population was at its peak. It was during this period that the adults were scarce. An increase in the adult population was noted from about the third week of July through the later half of August reaching its peak around 30th August. During this period a perceptible decline in the population of hoppers was noticed, being lowest for the rainy season on 30th August. It was, however, interesting to know that during the period that their population for the rainy season was at its peak, females out numbered males by 3:2.

The hopper population showed a marked increase in number from September onwards reaching its peak on 30th October. This increase in number was evidently due to the hatching of the eggs laid by the first generation females. During the period September through October when the hopper population was on the rise, the adults of both sexes showed a decline in number with the decline being more pronounced in females than in males.

With the onset of winter there was a sharp decline in the number of hoppers collected. This decline in the population of hoppers started from 15th November, reached its lowest for the winter on 30th December. It was during this period that the adults showed an increase in the number with the males reaching their winter peak by 30th of December. This can be explained as being due to the newly emerged adults of both the sexes - a phenomenon which corresponds with the noticeable decline in the number of hoppers during this period. During the period October through December males were more abundant than the females. From 30th December onwards the number of males started declining, and the females were more in number till the last week of January. The females having reached their winter peak by the same time as males (30th December) maintained it till 15th of February beyond which the adult population of both sexes declined reaching the lowest by 15th of March. This decline being more pronounced in males than the females.

During the period when adult population declined, hoppers started increasing in number. By 15th of March when adult population was lowest, the hoppers reached their third peak whereas number of males always remained higher between the period 15th October to 30th December. The population of the females was at its highest for the winter on 30th December and interestingly the number of females in a given sample was same as that of hoppers. From 30th December onwards hoppers were showing a trend of increase in their population with a decline in the number of females simultaneously, whereas the population of the males remained unaltered till 15th of February and then started declining while hoppers were showing an ascending trend in their population from January through March, the adult population of both sexes was gradually declining till it reached its lowest on 15th of March.

Once again with the onset of summer the hoppers population started declining from 15th March onwards while the number of adults started increasing, reaching their maximum on 15th of April. Beyond which once again their number started decreasing. The population of the hoppers declined constantly till the end of May when a hopper could rarely be caught or located in the field. The population of the adults declined suddenly in the last week of May and then their population was maintained at that low a level till the next rainy season.

Throughout the year emergence occurred thrice, being maximum out of the eggs laid by the first generation females during October

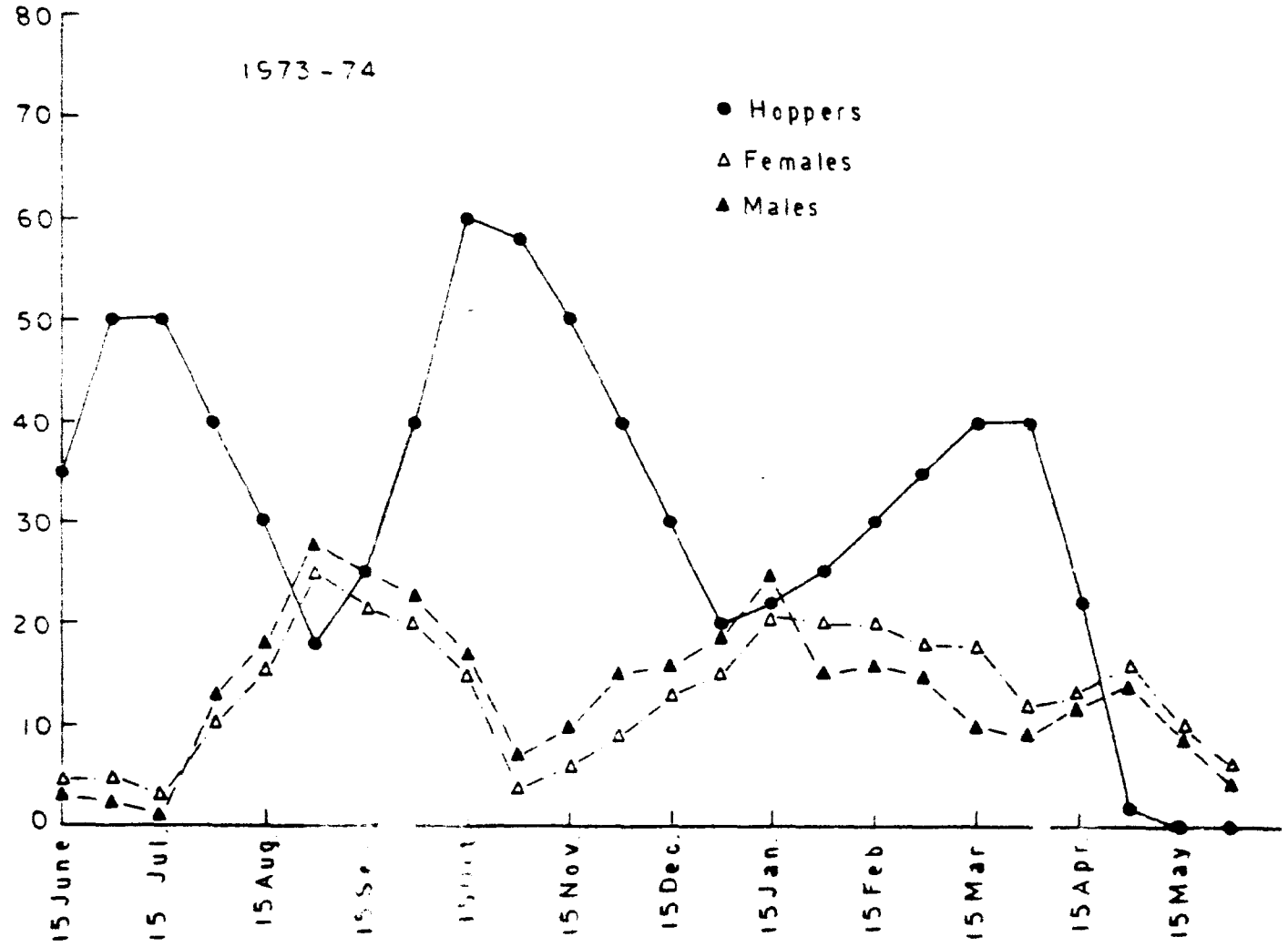

FIG. 19 SEASONAL FLUCTUATIO[illegible] THE POPULATION

through November. The highest peak for females was on 30th August while that of males on 30th December. The number of males was greater than the females during 15th July to 15th August and once again during the period 15th October to 30th December. During rest of the months in a year females remained more abundant than the males.

During the year 1973-74 almost similar trend of population fluctuations were exhibited by both the hoppers as well as the adults. However, the following changes were of interest (Fig. 19):

(a) Unlike the previous year the population of males was larger than the females during the period 30th July through 15th January beyond which it was reversed.

(b) During previous year a given sample on 30th December contained hoppers and females in the equal number while this year it was the number of males almost equaling the hopper at the same time of the year while the number of females almost coincided with the number of hoppers on 15th January.

(c) With the onset of summer the decline in the hopper population was sharper during this year as compared to the previous year.

(d) In general *O. velox* was less abundant than in the previous year.

(iii) General Observations:

The first part of the daily procedure is the awakening in the field, two factors, light intensity and temperature are changing rapidly at this time, both are increasing. Thus it is

possible that the hoppers exhibit positive photokinesis, positive thermokinesis or both. Most of the evidence from literature supports a thermokinetic response, but it must be borne in mind that more than one factor may operate at the same time and it has been suggested that light and humidity may be associated with temperature in the morning awakening. In field it is often difficult to separate the effects of light and the radiant heat.

Correlated with the morning increase in activity, hoppers of O. velox show a general movement of ascent from the overnight position. Soon they come to rest on the exposed surface of the leaf and remain stationary till the temperature along with light intensity, is further increased. Around 7.00 hrs hoppers become active again and start feeding. The early instar hoppers are quite wary even during feeding and a shadow or stirring due to wind may induce them to seek for shelter under the surface of the leaf.

Feeding was observed more frequently in cages where it usually took place between 8.00 hr to 10.00 hr and 17.00 hrs to 19.00 hrs. Since electric bulb was the source of light which was switched on and off at 7th hr and 19th hr respectively, visual stimulation could have played some role in addition to the set internal clock, as the food was changed every morning and evening. Both in the laboratory as well as in the field, it took some time for the hoppers to get adjusted and start feeding. There was observed a difference between the manner a grass blade was consumed by the hoppers or the adults

of *O. velox*. Invariably every time the hoppers feed along the margins of the leaf blade, they reach the upper half of the blade, have some exploratory bites and then their mandibles start working on the edge. During the process of feeding hoppers gradually keep retracting with their mandibles at a non-stop work. The depth upto which a grass blade is gnawed deepens with the development of the hoppers and a pinna is reduced to almost a stalk which is the left-over mid-rib. Among the adults the entire leaf is consumed along with the mid-rib and only the basal portion of the leaf is left. It was also observed at times that the cut leaf lying on the floor of the cage was held by the first pair of legs and guided to the mandibles. A careful observation of the folliage in the field can depict that which of the two stages is more in number at a particular site.

The feeding may be disrupted either by approaching a hopper or by ruffling of the leaves, as in both cases hoppers suddenly stop their activity and wriggle to the under-surface of the leaf. This activity is resumed once the environment becomes congenial again. In case if the hoppers are approached further, they simply drop off from the leaf to the ground and wriggle into the tuft of grass or else frantically hopp off and away. This reaction is present among the young hoppers without exception. Among the late instar hoppers the first part of the reaction is the same but once they reach the under surface retreat to the base of the plant while always maintaining an upright position.

When feeding is completed hoppers usually jump off to the adjacent folliage and rest for sometime or simply drop off to the

ground, then they become quiescent for sometime, the movement of antennae and palpi being the only trace of activity. After sometime there is observed a descent from the feeding site and the hoppers come to bask on the lower leaves under a cover, at 10-12 inches above the ground depending upon the plant's height. This descent after feeding could have been induced by a rise in temperature. It is supported further, as the hoppers were observed seeking shelter under the leaves with a rise in temperature and towards the peak hours of the day were found basking even at a lower height than the roosting site, which is around the base of the first leaf. Such a position is probably acquired to avoid the sun. Around mid-day some of the adults were observed taking short flights into the adjacent shady sugarcane field for shelter.

As the temperature starts falling around 16th hours, there is observed a second spell of activity among both, the hoppers and the adults. They start ascending from their shelter and this finally leads to feeding around 17th hr. The time taken in feeding is lesser towards dark than in the morning. In quite a similar fashion they descend after the feeding is over, reach at the basal part of the first leaf, where they roost. The roosting site is generally higher than the basking site.

During the entire survey none of the hoppers were found roosting or basking on the exposed surface of the leaf. The shelter is always taken on the under surface. Very young hoppers seldom stay at the tips of the grass blades but as they grow old start exploring the world with a keener interest. The

general activity among the hoppers was at maximum in the early morning hours and at dark. The behaviour of the hoppers is random and directed. Among the hoppers movement is in the form of foliage to foliage leaps and were not found marching or working. Among adults it is the short flights, but on coming in contact with the foliage, quickly move to the under surface of the leaf.

A search for O. velox through several crops revealed that it ingested only Oryza sativa and very rarely could be collected from Zea mays or Triticum aestivum. Only adults could be collected from an adjacent sugarcane field and that too between 11.00 hrs and 14.00 hrs, where probably they were in shelter, to avoid the sun.

CHAPTER - V

D I S C U S S I O N

The smaller rice grasshopper Oxya velox Feb. a paddy pest is reported from several countries like India, Japan, China, Malaysia and Indonesia. In India it is widely distributed and has been reported from Andhra Pradesh, Maharashtra, Madhya Pradesh, Orissa, Uttar Pradesh, Punjab and Rajasthan.

In general, both males and females are medium to small sized, females being slightly larger than the males, measuring 2.73 cm and 2.49 cm at an average respectively. Since it is found in humid tropical habitats of the eastern hemisphere, the considerable expansion of the hind femora ventrally along with the expansion of tibia beyond the middle and that of the first tarsal joint is an adaptation for swimming. Among the newly emerged adults the dorsal pigmented band appears light green and rest of the body as bright green, which later on after 4-7 days of emergence turns brown and the bright green colour becomes dull. The prominent bright pigmentation in this grasshopper diminishes with the advancement of age and just a day or two before their death, adults appear almost dull brown in general. This colour change is more brilliant among the females than the males. The colour changes during the life are particularly noticeable in gregarious Schistocerca where the young adults are pink while the old ones, bright yellow (colour illustrations given by Kunckel d'Herculais, 1893-1905; Loesener, 1905 etc.). The colour changes are further illustrated by Chauvin (1941b) and Norris (1954) among the cage bred Schistocerca where change from pink to yellow is more brilliant in males than the females while it is reverse among the Oxya velox adults. Since the

first change in colouration coincides approximately with the beginning of copulation, it may be assumed that it is correlated with the maturation of gonads although some authors (eg. Boldyrev, 1940) maintain that yellow colouration in *L. gregaria* is merely a sign of aging and not of maturation. However, such assumptions would be more convincing once supported by the study of the hormonal (N.S.H.) levels.

Changes in colouration are known, not only among gregarious locusts, but, also in some others like in African *Mesopsis laticornis*, where the development of a large black path on the hyaline wings may be associated with the onset of the reproductive activity but direct observations are needed (Burtt and Uvarov, 1944). Detailed study on British grasshoppers revealed changes in adult colouration, in most cases parallel to the maturation of gonads (Richards and Waloff, 1954).

However, in practice the coincidence of the darkening of the dorsal pigmented band in *Oxya velox* can be an approximate and useful guide for judging the onset of the reproductive phase as well as the growth potential in wild populations.

After the emergence, adults take some time to copulate and this pre-copulation period varies from species to species and even among the individuals of the same species. Males and females both in *Oxya velox* do not start copulating immediately after the emergence and the pre-copulation period varies from three to four days,

the average being 3.40 ± 0.15 days under the constant conditions in the laboratory at 30 ± 1°C with 70 ± 5% R.H. and fed on Cynodon dactylon, a common weed. Lui and Li (1933) found that the pre-copulation period lasted for 15 to 41 days in an allied species Oxya chinensis. Similarly Nishikawa (1935) reported a variation from 9 to 26 days in the pre-copulation period of Oxya species. Unlike others, the male Poicelocerus pictus has a longer pre-copulatory period but the female is copulated just after its emergence (Pruthi and Nigam, 1939).

The act of copulation is usually preceeded by a more or less elaborate courtship behaviour. The male of Oxya velox makes an advance towards the female by tapping over the antennae of the female with its own, and keeps sitting motionless. Then it suddenly jumps and mounts over the female's back. Now if the female is not receptive, it starts jumping vigorously and the male during its efforts to adjust properly, is separated. The male otherwise holds the female firmly with its fore legs at the frontal region while the claws grasp the lower margins of the frontal lobe. The middle pair of legs holds the female under its wings above the hind pair of legs, while the hind pair of legs do not take any part in the whole process. This is the typical rinding type of posture, most common among the acridids like Anacridium aegyptium (Fedorov, 1927); Locusta migratoria (Boldyrev, 1929); Melanoplus differentialis (Kyl, 1938); Poicelocerus pictus (Pruthi and Nigam, 1939); Schistocerca gregaria (Norris, 1954; Hunter-Jones, 1960); Locusta migratoria (Gregory, 1965); Melanoplus sanguinipes (Pickford and Gillot, 1972); Spathosternum

parasiniferum (Iqbal and Aziz, 1974); and Trilophidia annulata (Moonis and Aziz, 1977) etc.

Katiyar (1952; 1956b) however, observed "lateral" and "hanging" postures in addition to the most common (Riding) type, only among the species with the two sexes of dissimilar size like Parahieroglyphus bilineatus. The females of Oxya velox with males in-copula may continue to feed, crawl or even jump on disturbance. The copulation once disturbed may be resumed after a gap of 17 to 24 hours. Popov (1958) has also observed the same in Schistocerca gregaria, but, in some species with strong sexual dimorphism in size like Spanacris a female may even fly with the male attached (Bebard, 1937a). At the end of copulation the female starts jerking the hind tibiae and jumps vigorously, thus causing the seperation.

The duration of copulation varies from species to species. Fedorov (1927) in Anacridium observed that the pair remained united from 18 to 60 hours. Nakhla (1957) in Eyprepocnemis plorans observed that the copulation period was 1 to 4 hours which sometimes extended upto 6 hours or a whole day under the laboratory conditions. The copulation period among Spathosternum parasiniferum varies from 8 to 49 hours (Iqbal and Aziz, 1974) while it varies from 40 to 60 minutes in Trilophidia annulata (Moonis and Aziz, 1977), which is almost of the same size as the former grasshopper. Thus a longer copulation period can not be correlated with the size of the grasshopper, but one should distinguish in such observations (i.e. longer copulation periods) between the pairing and the actual copulation, that is the process of sperm transmission, the length of which

depends largely on the rate of spermatophore formation.

The complete act of copulation in O. velox takes 2 to 4 hours in the cages while in the field it takes 30 to 90 minutes. This shortening of the copulation period in the field may be attributed to the extreme wariness of the adults under the natural conditions where, even a scratching sound could seperate the copulating pair; they would jump up explosively and fly off in different directions. The female of O. velox copulates several times (5 to 6 times at an average) before or after each oviposition, but the repeated copulations are not necessary for the successive ovipositions. However, the total fecundity is influenced favourably due to the repeated copulations. Similar observations have been made by Fedorov (1927) in Anacridium; Norris (1954) in Schistocerca; Ivanova (1925, 1926) and Gregory (1965a & b) in Locusta where they observed more than one spermatophores in the females, indicating that it allowed copulation to be repeated as many times. However, Hunter Jones (1960) suggested (by crossing the albino female with the normal male and then with the albino male) that the latest fertilization was the effective one in Schistocerca. Another point of substantial interest is that a single copulation is sufficient to fertilize a number of successive egg-pods as shown by Norris (1954) in Schistocerca.

Female O. velox deporites its eggs in the moist sand after having selected the suitable site with the help of antennae, palpi and the ovipositor valves. The former two parts detect the moisture

level with the help of hygroreceptors while the latter test the compactness of the bed. The process has already been described and includes thrusting with alternate collapsing and expanding of the ovipositor valves along with the extension of the abdomen. Females failed to lay eggs in the phyriologically dry soil, and then as an adaptive radiation, eggs are deposited on the foliage (Plate 5, Fig. 1), which is in agreement with the observations made by Rao (1921) on the same grasshopper under the water logged conditions. Similar observations were made by Pradhan and Peshwani (1941) in Hieroglyphus nigroreplatus where eggs were deposited among the roots of the various shrubs. The variation in the site of oviposition from species to species is probably due to the moisture requirements of the eggs to develop and the water retaining capacity of different soil beds, as, a female Colemania sphenerioides oviposits in the black soil (Uvarov, 1928), Oedaleus senegalensis in clay (Joyce, 1952), Aularches punctatus in sandy loam (Katiyar, 1955). In case where the soil is extremely dry, females failed to oviposit at all (Norris, 1968; Edward and Epp, 1965) and sometimes the female dies without egg laying (Katiyar, 1956).

The process of egg laying among the females of O. velox is the typical acridid type and the pre-oviposition period at an average is 9.00 ± 0.39 days under the constant ecological conditions of 30 ± 1°C, 70 ± 5% R.H. and Cynodon dactylon as food. Iqbal and Aziz (1974) reported 9.7 ± 0.36 days as pre-oviposition period in Spathosternum prasiniferum Walk.

The female gonads at adult emergence are not as advanced as those of the male, and females lag considerably behind males in their maturation, moreover, Boldyrev (1940) recorded that the males of Locusta m. migratoria kept at 20-25°C produced spermatozoa which failed to reach the seminal vesicles, these males copulated, but their spermatophores were without sperms. Thus in all experimental work the time from emergence to the first oviposition (pre-oviposition period) is designated as the maturation period.

The female of O. velox makes a burrow, 1 to 2.5 cm♀ deep in the soil. Once again the depth of the burrow varies from species to species depending upon the length of the abdomen as well as the extension of the elastic intersegmental membrane, eg., in Anacridium aegyptium the female abdomen extends from 3.5 to 9-10 cm♀ (Fedorov, 1927); 8 to 10 cm♀ in Atractomorpha crenulata (Agrawal, 1955); 2.0 to 7.7 cm♀ in Aularches punctatus (Katiyar, 1955), 3 to 4 cm♀ in Cyrtacanthacris ranacea (Makhla, 1957); 4.5 to 17 cm♀ in Acrida pellucida (Hafez and Ibrahim, 1958) and 2 to 3 cm♀ in Trilophidia annulata (Moonis and Aziz, 1977). The female of O. velox takes 30 to 60 minutes to complete the oviposition, and oviposits 6 to 7 times during the entire oviposition period of 17.00 ± 1.60 days under the constant experimental conditions. The time taken in a complete act of oviposition varies from species to species and depends upon the number of eggs laid at each oviposition. Iqbal and Aziz (1974) recorded that 2 to 4 hours were required for Pathosternum parasiniferum to complete the oviposition, while only 45 to 60 minutes by Trilophidia annulata (Moonis and Aziz, 1977).

This variation in duration, however, does not correspond to an almost negligible difference in the number of eggs deposited at each oviporition by these two different species.

The temperature affects maturation as well as oviporition in C. velox Lab. The effective range of temperature for the maturation of the females is 15 to 40°C; and a rise in temperature within this range enhances the maturation of gonads. The females did survive at 10°C for a shorter period but failed to oviposite. The effect of humidity on the above mentioned aspects is significant only at the higher extreme of the survival temperature i.e. 45°C where oviporition could occur only at 90 ± 5% R.H. It may be suggested that such a high level of humidity reduces the desiccating effect of such a high temperature and prevents the excessive loss of water from the body which otherwise affects the addults fatally. The maturation and oviporition both have a linear relationship with the temperature. However, it is interesting to note that a humidity level upto 70 ± 5% R.H. does not affect the oviporition period at any level of temperature but a higher level (90 ± 5% R.H.) shortens it slightly.

It is quite probable that under the natural conditions, which would not be as rigidly constant as in the laboratory, the effective range of temperature for the maturation of gonads, could be broadened. As Dudley (1951) found that the crowded Chirotocerca at rigidly controlled constant temperature of 35°C with all other conditions also kept constant, failed to mature for as long as

seven to eight months and then died. Males developed the normal pink coloration but when it disappeared, they did not become yellow. Dissection of the females showed that the yolk appeared in the ovarioles much later ~~than normally~~ and its quantity was deficient. Hamilton (1936, 1950) performed extensive experimental work on Locusta and Schistocerca with various combinations of temperature and humidity. The shortest maturation period for Locusta was 12 days at 40°C with 70% R.H. where as for Schistocerca it averaged 17 days at the same humidity but with 36.7°C. These highest rates of maturation, however, resulted in the shortest life span. The shortest maturation period for the female of O. velox was 3.80 ± 0.34 days at 45°C with 90 ± 5% R.H. Iqbal and Aziz (1973) in C. parasiniferum observed a reduction in maturation as well as oviposition period with a rise in temperature and also that humidity did not have any significant effect, which is contradictory to the present findings with Oxya velox (Fab.).

The variation in the size and shape of the egg-pod is related to the moisture, the food of the parents and the number of egg-pods laid previously (Norris, 1950), the nature of the soil (Hilliard, 1959), but basically it is the size and the number of eggs in each pod which in turn determine the size of the pod. The number of eggs in each pod or a clutch can never exceed the total number of ovarioles, and usually there is a good agreement in the mean number of ovarioles and of eggs in a clutch (Richards & Waloff, 1954). Although most of the small sized grasshoppers (Gomphocerinae and Acridinae) have low egg numbers. Yet the clutch size is of little

taxonomic value since closely related species may have very different numbers eg. 5 to 13 in Dociostaurus brevicollis and 19 to 24 in O. tartarus (Uvarov, 1966).

Among Oxya velox the egg-pod measures 1.4 to 3.6 cms long and 0.4 to 0.9 cms in diameter, having 6 to 14 eggs per pod. The average number of eggs per pod is found to be 9.00, and the average number of egg-pods per female is 6.20 ± 0.41. The total number of eggs laid by a female in its entire reproductive life (fecundity) is 56.40 ± 3.92 at 30 ± 1°C and 70 ± 5% R.H. while fed on Cynodon dactylon. The number of eggs laid at each oviporition remained almost unchanged upto the third oviporition, beyond which it declined gradually, thereby partly explaining the suggestion made by Morris (1950) regarding the shape and size of the egg-pods. The present observations support the ones made by Moriarty (1969), who reported a decline in the egg laying capacity with the advancement of age in Chorthippus brunneus. The total number of layings by a female primarily depend on the length of the period during which the female continued its reproductive activity. The males need not be considered, since a single copulation is sufficient to ensure repeated fertilizations.

The length of the adult life and of the reproductive period are affected by external conditions in a similar way but their effect on fecundity are different. Gomphocerus pellucida survived at 37°C for only 15.8 days, but 4.2 egg-pods per female were laid during that time, where as at 27°C the life span was doubled (32.6 days), but only one egg-pod per female was laid (Parker, 1930).

In Locusta the maximum number of eggs per pod and of viable eggs was obtained at a constant temperature of 26.7°C and in Schistocerca at 32.2°C. In the case of fluctuating temperatures, however, these optima are at a considerably lower mean temperatures namely 25.1°C for Locusta and 23.5°C for Schistocerca (Hamilton, 1950). Iqbal and Aziz (1973) recorded the highest fecundity at 35°C with 75% R.H. while the optimum temperature for the survival of the eggs was 30°C in *E. parasiniferum*. The present experiments with Oxya velox Fab. revealed that the fecundity was maximum at 35°C and 90 ± 5% R.H. where females lived for 29.8 ± 1.89 days and laid 64.80 ± 1.68 eggs at an average, while at 15°C with the same humidity it lived for 41.10 ± 1.28 days but laid 47.00 ± 1.00 eggs; a reduction in fecundity by almost 28%. A rise in temperature from 15°C to 35°C proved to be favourable for the egg production but the fecundity got adversely affected by a further rise in the temperature. Higher humidity (70% or 90%) was favourable for high egg production and especially so at the upper extreme of temperature i.e., 45°C where fecundity, though highly reduced was still realised only at 90 ± 5% R.H.

If the adult period of a species in nature overlaps the unfavourable (cold or dry) seasons, the longevity of the adults depends primarily on their ability to survive the extreme conditions. For example the mean longevity of Chorthippus brunneus females in the field in Britain was 36.5 days but in the laboratory they lived upto 73 days (Richards and Waloff, 1954). Adult Dociostaurus maroccanus in Cyprus during the dry summer period survived for 63 days in the field and upto 114 days if kept in cages and given fresh

grass (Waterston, 1951). Thus suggesting thereby the importance of the availability of food.

Since males are much less liable to expend their reserves in reproduction, one would expect them to be generally longer lived than females. This holds true for Oxya velox (Fab.) where males at an average survived for 39.80 ± 1.57 days, while the females for a shorter period of 29.9 ± 1.68 days. The few available data are contradictory as the adult males of Atractomorpha crenulata lived in cages for 25 to 30 days and females for 30 to 68 days (Agrawal, 1955). The isolated Nomadacris males in the laboratory lived generally much longer than the females, the maximum period recorded being 310 days as against 137 for the females (Norris, 1959). On the other hand, males of Anacridium in the laboratory lived for 78 to 99 days as against 202 to 308 days for the females (El-Zobeiry, 1937). Thus a generalization can scarcely be made. However, the differential survival of the two sexes may have a striking effect on the adult sex ratios in the field populations, as was pointed out by Popov (1954) who recorded that in immature swarms of Schistocerca the sexes are approximately equal in number, but towards the end of oviposition period females die off before the males, with a result that the swarms come to consist almost entirely of males. Field records of the sex ratio in populations of uncertain age, are therefore of little value. The longevity of the adults of O. velox was maximum at 15°C and either an increase or decrease in temperature shortened the life span. However, it was interesting to note that a decrease by 5°C resulted in a much pronounced shortening than was caused due

to an increase by the same number of degrees. The humidity affected the life span favourably only when it was increased from 60 ± 5% R.H. to 70% or 90% R.H. at any level of temperature. The survival of the adult was also affected in the similar manner as the maturation. Highest percentage of survival was obtained at 30°C. Below or above this temperature it declined gradually but still the survival range of temperature was greater among the adults than the hopper and also that the survival was affected favourably by the increased humidity at any temperature. It was also revealed that the females of Oxya velox are better resistant towards the adverse conditions of temperature and humidity than the males. The probable explanation for the favourable effect of high humidity at high temperatures lies in counteracting the desiccating effect of the high temperature.

The eggs of O. velox in a pod are generally arranged in longitudinal rows. Chenier (1939), observed in Oedaleus nigrofasciatus that the eggs where arranged longitudinally in rows and groups of four each. In O. velox (Fab.) the pod is usually 2 to 3 chambered, the apex of which points upwards while its case is round with micropylar ends of the eggs pointing downwards. Chapman and Robertson (1959) in Oedaleus nigeriensis observed that the egg-pod was 6 to 10 mm long, while plug length was 6 to 20 mm, eggs were bilaterally symmetrical with single vertical series of four parallel or subparallel rows in a pod.

The eggs of O. velox are laid in moderately damp soil and are roughly banana shaped measuring 0.392 cm long and 0.118 cm in diameter. The freshly laid eggs are yellow in colour which

changes to almost brown just two or three days before hatching. Among acridids the egg's length is usually about 4 to 5 times its diameter, though in Euthystira the ratio is about 3, while the eggs of Acrida are about 8 times as long as wide (Hafez and Ibrahim, 1950). Considerable individual variation in the egg size occurs and moreover a substantial increase in the size during the course of development has been reported by several workers like Roonwal (1936a) in Locusta migratoria, but an exception to this generalization has been reported by Bhulov (1952) where in few highly xerophilous species like Tmethis pulchripennis eggs do not increase in size. In case of O. velox eggs increase to 0.4 to cm from 0.392 cm in length and 0.132 cms from 0.118 cm in diameter after 17 days of incubation at 30 ± 1°C temp. with 70 ± 5% R.H., while the average incubation period for the complete development is 20.80 ± 0.12 days. Under the same temperature and humidity conditions. The chorion becomes thick with pronounced granulations, which could be a cause for the change in colour from yellow to brown. Kumashiro (1935) in Oxya vicina reported the incubation period of 14 to 20 days at 27°C and 35°C, while in Oxya velox it was found to be 13 and 19 days at the above mentioned temperatures. Iqbal and Aziz (1976) reported the incubation period being 20 to 22 days in Pathosternum paraniniferum. While in Trilophidia annulata it was 21.4 ± 1.933 days (Moonis and Aziz, 1977). Similarly the reports obtained from several workers have been of quite unequal value, however, it is interesting to note that a comparison of incubation periods of different species at a reasonable range of about 30°C to 32°C show apparently that the incubation period of many species, tend to be on the whole,

fairly uniform at about 14 to 20 days (Uvarov, 1950). The average percentage of hatching in O. velox at 30 ± 1°C and 70 ± 5% R.H. was 89.1 ± 2.30.

The incubation period as well as the percentage of hatching is affected by the contact moisture level. It may also be suggested that first 10 days after the oviposition, is the initial crucial period when sufficient contact moisture is necessary for the development of the eggs. The water absorbed by the eggs in the initial stages is sufficient for the completion of the development. However, it is not true for the eggs, as the maximum percentage of hatching was obtained when the optimum contact moisture level (12%) was provided throughout the incubation. Lower or higher level than 12% of the contact moisture retarted the rate of development slightly but its effect on the percentage of hatching was more prominent. The eggs failed to hatch in the physiologically dry soil. Similar findings have been reported by Farmer (1929) where a high percentage of hatching was obtained in moderately damp soil than in the wet or dry soil. The extension in the incubation period due to the deficiency of water has been reported by Hussain et al. (1941) and Shulov and Pener (1961, 1963) in F. gregaria. Shulov (1950) further reported an extension upto two months in the incubation period of the eggs in Anacridium aegyptium which otherwise hatch in 30 days, when there is no water deficiency. However, the present experimental work did not reveal such a pronounced prolongation in the incubation period due to water deficiency instead the mortality increased which probably indicates the susceptibility or vulnerability of the

Oxya velox (Fab.) eggs to the very obvious change in the optimum conditions for the development.

A further point is the effect of incubating temperature on the daily rate of development and the percentage of hatching. A sudden reduction in the percentage of hatching was observed at the extreme temperatures. The maximum percentage was obtained at 35°C with 12% contact moisture, however, there exists a linear relationship between the temperature and the daily rate of development. The incubation period is significantly affected by the change in temperature but the contact moisture does not have any significant effect. The effect of contact moisture alone is significant only at the extremely high temperature where greater number of eggs could complete the development, as the water loss due to high temperature was probably compensated by the high contact moisture level. Some what similar observations have been made by Grewal and Atwal (1968) on incubating the eggs of Chrotogonus trachypterus at different levels of temperature and humidity, found that the incubation period was inversely proportional to the rise in temperature but humidities between 4% and 12% did not have any significant effect. Shulov and Pener (1963) in Dociostaurus, Hunter Jones (1964) and Harjai and Sikka (1970) in L. gregaria found that too low or too high a moisture level affects the development of the eggs quite adversely. Similarly Iqbal and Aziz (1973) in E. paracinliferum and Khan and Aziz (1973) in Oedaleus abruptus observed a direct and positive effect of the temperature on the development of eggs.

The exposure of the freshly laid eggs of O. velox to the fluctuating temperatures revealed that the low temperature retards the development but when it is altered with high temperature it acts as a stimulus for the development of the eggs, but a shorter exposure to low temperature is a stronger stimulus for the eggs kept at high temperature otherwise. The same low or high stimulating temperatures turn fatal if the time of exposure is increased to 3 days. Somewhat similar observations were made by Sodine (1925a) on some other orthoptera.

All the nymphs from a single pod emerge in about 10 minutes and their covering membrane is cast off while trying to wriggle out of the burrow. This membrane in the past was regarded as the amnion but Sharan (1958) described its formation during the embryonic development and since it is without cellular structure and is a true cuticle, it is called as provisional cuticle. The vermiform larva is therefore a real first instar. Such a special name is given to avoid confusion in numbering the free hopper instars (Uvarov, 1928). The vermiform larva of Oxya velox has already been described.

The number of hopper instars may vary from species to species in Acridids and even among the individuals of the same species. There are 6 nymphal instars in O. velox (Fab.) with the mean nymphal duration for males and females being 38.00 ± 0.39 days and 41.00 ± 0.48 days respectively. Some times an additional moult was observed among the females only, as has also been reported by

Rao (1921). Kumashiro (1935) and Thakham (1940) reported 6 instars in males and 6-7 instars in females among Oxya spp. Hodge (1933) reported that an additional instar in Acridids is due to the different size of male and female hoppers. He reported further that there is no correlation between the extra instar and food or sex, while May (1936) assumed that the additional instar is an inherited character, and temperature or relative humidity has no effect on it.

The different nymphal instars could be identified on the basis of the body size, antennal length, external genetilia and the wing-pads. During recent years, some similar observations have been made by Antoniou (1973) in Ornithacris turbida, where he observed 6 nymphal instars with the mean nymphal period for males and females being 59.9 ± 3.8 days and 78.7 ± 3.2 days respectively. Iqbal and Aziz (1974) in Spathosternum parasimeferum observed 6 nymphal instars with 37.58 ± 0.28 days and 44.25 ± 0.883 days as nymphal periods for males and females respectively. Majeed and Aziz (1975) reported 4 to 6 instars in males and 6-7 instars in females of Gastrimargus transversus. Noonis and Aziz (1977) reported 5 nymphal instars in both the sexes of Trilophidia annulata with the mean nymphal durations being 28.7 ± 0.994 days and 40.4 ± 1.52 days for males and females respectively.

Temperature and humidity both have a significant effect on the rate of development and survival of the hoppers. Effects of temperature and humidity should be discussed together as it is extremely difficult in the experimental work to separate the two factors. The variation of the relative humidity with the temperature

was ruled out with the help of the constant temperature room, yet hopper metabolism is possibly affected more by the water contents of the food rather than the relative humidity, which may influence the quantity of the food consumed and therefore, the rate of growth. The frequent replacement of the fresh weed minimised the lesser food consumption effect on growth which otherwise would be evident due to wilting of the leaf at low air humidities. Nevertheless the extensive experimental work conducted by Parker (1930); Hamilton (1936, 1950); Husain et al. (1940); Chauvin (1941b); Khan (1949); Dudley (1961); Grewal and Atwal (1968); Antoniou and Hunter-Jones (1968); Pradhan and Pachwani (1961); Parihar (1971); Khan and Aziz (1973) and Iqbal and Aziz (1974) on several acridids revealed a clear shortening of the total nymphal duration and an accelerated rate of development with the rising temperatures.

The nymphal duration among both the sexes of Oxya velox (Fab.) is affected by temperature and humidity on the similar pattern as has been observed in other acridids. It was longest at 10°C and shortest at 40°C while none survived at 45°C. The conditions for the shortest nymphal duration and the maximum percentage survival do not coincide since development was fastest at 40°C while the lowest mortality occurs at 30-35°C. Similar observations have been made by Hamilton (1950) on Locusta and Schistocerca. Contradicting to the Hamilton's finding are the observations made by Husain, Ahmad and Mathur (1940) whose experiments proved beyond doubt that relative humidity had no effect on the hopper development. Apart from the fact that their conclusion was based on very few experiments, these authors provided hoppers with unlimited green food, thus counteracting the effects of

low air humidity while Hamilton ured food plants partly wilted to approximately the same water contents. Dudley (1961) also found no difference in the rate of development of Schistocerca hoppers at air humidities ranging from 30 to 90% but the hoppers had access to the drinking water. Chauvin (1961b) claimed that Schistocerca hoppers developed best at a relative humidity very close to zero. It was not mentioned whether such a low level of humidity was measured and also that it could hardly be achieved in a cage with one side covered with wire net admitting the out side air, while the food provided was fresh grass of lettuce with the stalks (out side the cage) in water.

However, the present experiments with Oxya velox hoppers revealed the significant effect of the humidity. It is clearly indicated that the survival range of temperature for the hoppers is decreased at 40% R.H. as compared to 70 ± 5% or 90 ± 5% R.H. The effect of humidity substantially modify the effects of temperature, particularly in the higher range of the later, as maximum number of hoppers could successfully reach the adult stage at 45°C with 90% R.H. and also that the percentage of survival decreased at 70% R.H. whereas none could survive even at 40°C when the humidity was as low as 40%. It was also revealed that the female hoppers were better resistant to the changes in the humidity as compared to the male hoppers. This could probably be due to the difference in the size of the two sexes.

Vegetation has been shown to control the distribution of the grass-hoppers both by its influence on the microclimate and by its restriction of the insect's diet. Oxya velox (Fab.) has been reported to have caused as much as 20% damage to the paddy crop (Rao, 1921). A correlation between the food plants and the distribution of the grass-hoppers has been observed by Vestal (1913); Hubbel (1922a & b); Strohecker (1937); Urghart (1941) and Cantral (1943) in north America and Anderson and Wright (1952) in Montana.

The distribution of O. velox was basically restricted to the paddy fields, but it was also found feeding on Triticum aestivum, Zea mays and Pennisetum typhoideum among the cereal crops and Echinochloa colonum, Hemarthria compressa, Setaria verticellata and Cynodon dactylon among the weeds commonly found in the paddy fields. Since this grass-hopper is confined in its diet to one or comparatively few plants, its range is restricted to territory within their distribution. Similar view was held by Criddle (1933) who studied the biology and food habits of the grasshoppers in Canada.

The breeding place for this grasshopper is the turf area in between the water logged patches and all along the raised boundary of the field where, apart from Cynodon dactylon, equally succulent and palatable weeds like E. colonum, H. compressa and S. verticellata also grow, and this substantiates the almost unchanged distribution of the very young hoppers as was observed during the field survey. It was observed that the early instar hoppers (1 to 3rd) show a marked preference for weeds over the cereal crops but the preference for the latter increased as the development progressed. This is

another reason why, more advanced stages were collected from the cereal crops. Thus it may be suggested that this grass hoppers selects only those plants which are favourable for its development and also that the preference for food changes with age. Similar observations have been made by Rubtsov (1932a & b) in Siberian acridoidea; Pfadt (1949b) in A. elliotti; Scharff (1954) in M. mexicanus and Misra (1962) in C. pellucida. It was also found that Oxya velox completely avoided to feed on Trifolium alexandrinum which was cultivated in rotation with paddy. However, the hoppers as well as the adults did not migrate from their territory and could survive successfully on weeds previously mentioned which were not particularly removed from the field as T. alexandrinum happens to be a fodder crop. Iqbal and Aziz (1975) are of the opinion that a plant is preferred on the basis of its succulence nutritive value and the palatability. This opinion is primarily based upon the rejection of the plants like Solanum melongina, Solanum nigrum, Saccharum officinarum and Abelmoschus esculentus by Spathosternum prasiniferum. This contention is not entirely immune to criticism as T. alexandrinum is cultivated and used as fodder due to its succulence, nutritive value and is not tough in texture either, yet it is totally avoided by Oxya velox (Lab.). Hence it may be suggested that the preference for a specific plant is based upon a "factorial complex" including physical factors, availability of plants and lastly the chemical composition. It was observed during the present work that Oxya velox was attracted to the food either by distant chemoreception or by vision, or possibly by both. It appeared that no discrimination could be made between the preferred

and the unpreferred food unless a contact with the plant was made and even then it seemed that a bite into the plant was necessary. Such an observation probably supports the aforesaid contention.

Although the technique employed in measuring food preferences was sufficiently good to show that Oxya velox is a selective rather than a general feeder, a more precise method would have been desireable as the technique employed was not very quantitative.

Observations on the nymphal duration, survival of nymphs, fecundity, fertility of eggs and the longevity of the adults in relation to different food plants revealed that an unpreferred food plant had an adverse effect on all the above mentioned features. The nymphal duration is prolonged where food is of a low preferential value and that the female hoppers are affected more than the male hoppers. Similarly the greater number of hoppers survived on a preferred food plant. Food influences reproduction and striking differences in the fecundity of O. velox fed on different plants had been observed. Maximum number of egg-pods per female were obtained when food was the mixed diet which had highest preferential value, contrary to it, food of the least preferential value reduced the egg-pods by almost 60%. It has clearly been indicated that the number of eggs in each oviposition is greatly affected by the food and has a positive corelation with the preferential value of the food plants as the maximum fecundity is realized on the mixed diet and the minimum on the least preferred one. Similar observations have been made by Tauber, Drake and Beamer (1945),

Pradt (1949), Moshanchikov (1950), Barnes (1955), Pickford (1959), Karelina (1960) and Iqbal and Aziz (1977).

The females of Oxya velox show a negative corelation between the longevity and the preferential value of the food which is prolonged on an unpreferred food. Thus, the total fecundity appears to depend on the relative value of a food plant, both for the survival of the female and for the reproductive metabolic activity. The two effects may be very different since Oxya velox lives much longer on P. typhoidium, than on the other food plants, but its fecundity is very much reduced, while the females on the mixed diet have shortest life span with the highest fecundity.

The most intriguing result of the present work was that fecundity on a mixed plant diet was higher than the highest on any individual plant. This is in conformation to the observations made by Pickford (1959), on Melanoplus sanguinipes and Karelina (1960), on Chorthippus albomarginatus. Reasons for such an effect are obscure since the plant most favourable for reproduction to reasonably contains some essential chemical materials, and a dilution by less valuable food can hardly be beneficial. It is, therefore, suggested that the admixture of less valuable food stimulates the feeding activity and more food is taken, but possible effects of the quantity of food on fecundity have not been studied.

Hence, the present study has shown that all plants do not have equal food value for Oxya velox Fab. These variations may have been due to differences in the nutritive qualities of the plants themselves or due to differences in the quantities of food eaten by the grasshoppers or both. However, there are some indications that the differences were due to the quality factor. The positive correlation between the results of food preferences and the results on survival, growth and egg production, together with the observations that Oxya velox fed freely on the favourable plants and not on the unfavourable ones, suggests the importance of the quantitative factor. Nevertheless, these observations do not preclude possible quantitative differences being at least partially responsible for the observed differences in growth and egg production. Since it has been observed that the early instar hoppers of Oxya velox, develop better on weeds, de-weeding in and around the paddy fields could restrict the population to quite an extent.

Several workers have recorded the preference of various insects in a gradient of humidity at constant temperature. Key (1936) found that the third fourth and fifth instar hoppers of the African migratory locusts were more active in dry air than in moist air. Kennedy (1937) found that the African migratory locust preferred dry air in all parts of the humidity range at constant temperature of 30°C. Gunn and Cosway (1938) found that Blatta orientalis L. preferred drier conditions, but on desiccation exhibited a tendency to become hygroporitive. The reversal of reaction on desiccation has been observed in other insects as well, probably in order to

compensate for the water loss. This contention has been supported by several workers, especially so among the acridids.

Reactions of the hoppers (1st to 6th) of Oxya velox to three physical factors namely temperature, relative humidity and light have been studied in an alternative humidity chamber, designed to give an enclosed space with gradients (low and high) of humidity. The temperature 30°C and 15°C were so chosen as, the higher is quite short of thermal death point, and the lower is well beyond that where spontaneous movements would be possible, thereby affording a maximum contrast in the activity. Since Oxya velox like other acridids is phototropic, its reactions towards the gradient of light (high and low) were also recorded. The present experiments were based on the same plan as conducted by Aziz (1957 and 1961) on Schistocerca gregaria (Forsk). However, a major difference was in the use of undesiccated and fed hoppers of Oxya velox in order to avoid any distressed or forced reactions eg. Willis and Roth (1958) observed that the preference for wet region by adults of Tribolium castaneum was reversed to a dry reaction once the insects were given water to drink.

All the six instars of Oxya velox are hygropositive and tend to stay in the wet half of the chamber. The reaction becomes even more consistent and intense with a high light intensity, but in the identical apparatus Locusta shows a more intense and consistent reaction in the opposite direction (Kennedy, 1937) and also that the time spent active is affected by both low and high humidity, whereas

in Schistocerca it was different; the duration of the activity was significantly affected by light in the first instar and by light and temperature in the fourth instar hoppers (Aziz, 1957). Kennedy (1939) came to the conclusion from the field observations that Schistocerca hoppers were active in high light and inactive in the dim light. The observations on O. velox hoppers agree generally with those of Kennedy. The time spent active and hopping is significantly affected by light. The early instar hoppers hop more and march less than the late instar hoppers which agrees with the observations made on Schistocerca hoppers by Hussain (1937); Ellis (1951) and Aziz (1957). Although the present experiments were performed with only one gradient of R.H. yet the zone of minimum activity for Oxya hoppers i.e., wet half, corresponds with the optimum humidity for its development which, by the present experiments was found to be 70% to 90% at 30°C to 35°C. At 30°C the activity is significantly increased along with a definite hygropositive reaction. A number of authors; Bodenheimer and others (1929) working on Schistocerca gregaria; Parker (1930) on Melanoplus mexicanus (Saus.) and Camnula pellucida (Scudd); Hussain (1937) on Locusta, Schistocerca and Nomadacris; Kennedy (1939) and Aziz (1957, 1961) on Schistocerca found positive thermokinesis which are supported by the present finding on Oxya velox.

The general activity is decreased at low temperature (15°C) but when such a low temperature is coupled with low humidity or high light intensity (2.1 L.F.U.). there was a reversal of reaction. Chapman (1958) observed that the movement of Locusta hoppers was

restricted below 20°C but it was not inhibited completely. Hence, on these grounds it seems unlikely that low activity caused by low temperature could prevent photokinesis, which was positive among Oxya hoppers. Fraenkel (1929) and Kennedy (1939) found a decrease in positive phototactic effect in Schistocerca above 35°C but latter author found little response. He also found an increase in activity on sudden cooling.

Temperature and light both directly affect hopping and movement of other body parts among Oxya hoppers, whereas turning is basically influenced by the humidity and is always more in the dry half to avoid low R.H. Aziz (1957) observed the same in Schistocerca gregaria. He also observed that the activity of the hoppers decreased beyond 70-80% R.H. whereas the time spent in both the halves was not well marked at 50-60% R.H. and this was attributed to starvation which led to the restlessness. Since the increase in activity is attributed to the restlessness due to unfavourable conditions, then, according to him, Schistocerca hoppers felt at ease when the humidity was above 80% R.H. which agrees with the present findings with Oxya hoppers rather than the ones obtained by other workers on S. gregaria. The observations made by Ellis (1951) agree with those of Aziz (1957) that the activity measured in terms of the number of hops per unit time was always less in the fourth instar hoppers of S. gregaria than the first instar. It was observed among Oxya velox that the activity of hopping decreased gradually as the development progressed. Under all conditions it was less in the late instar hoppers than the early instars.

Fraenkel (1929, '30); Karandikar (1933); Hussain (1937); Kennedy (1939); Volkonsky (1939); and Aziz (1957) have studied the effect of light on the activity of S. gregaria hoppers and obtained positive phototactic and photokinetic response. The present observations are in agreement with those on S. gregaria. The hoppers of Oxya velox Fab. prefer the wet half of the chamber and the activity was minimum at 15°C with 0.7 L.F.L. Since positive photokinesis and thermokinesis has been observed, this reduction in activity cannot entirely be attributed to the ideally preferred conditions for the hoppers.

The field observations on the behaviour of the hoppers revealed that both, the awakening activity and ascent from the overnight roosting place, were initiated by the increase in light intensity as well as in temperature, and both depend upon the solar input. This is in confirmation to the laboratory findings regarding the hoppers being positively photokinetic and thermokinetic. However, it was interesting to note that the morning ascent was followed with a slight descent around mid-day, probably in order to seek shelter to avoid either the temperature or the light, whichever became unbearable. Hence it may be suggested that beyond the threshold of the hoppers there is "reversal of reaction", which could only be determined by exposing the hoppers to these two factors independently. It was also observed that at 16th hour there was another spell of activity, when the intensity of light was definitely lessened. Since the three major physical factors namely temp., light and humidity are inter-dependent and inseparable under the natural conditions, they affect the organisms combiningly and hence the optima

obtained from the laboratory experiments are difficult to be found in the natural surroundings. Michel (1973) also found that the light and dark affected the initiation and cessation of the flight in *L. gregaria* reared in isolated or compact groups.

Wikerson (1963) found that locomotor activity of *locusta* conditioned to light or dark varied quantitatively but in both period of activity was followed by the resting phase. Something similar was observed in *Oxya velox* Fab. where the morning ascent was followed by a resting phase before the feeding started in the field, and then once again a quiescent phase after it was over. The behaviour of the hoppers in general was random and undirected. The actual aggregating tendency was lacking, but the very young hoppers tended to clurter, probably as a result of the initial cohesion among the hoppers from the same egg mass.

The daily movement of the hoppers as well as the adults has been studied in detail in *Nomadacris septemfasciata* by Burnett (1951) and in *Locusta migratoria* by Chapman (1955). The present findings with *Oxya velox* hoppers generally agree with the ones made by Burnett and Chapman. However, there were a few differences like the roosting site among the above two was much higher than that of *Oxya velox*, where it is at the basal part of the first intercostal region. *Oxya* hoppers start a morning ascent with the rise in the intensity of light as well as the temperature. While in *Locusta* and *Nomadacris* the first movement is the descent

from the overnight roosting position which was about 4-5 ft. above the ground and then they come to rest on the ground till the temperature does not become unbearable, otherwise they were found to be seeking shelter in order to avoid the sun. Suggesting thereby a reversal of the positive photokinesis or thermokinesis (Chapman, 1955).

Between 11.00 - 13.00 hrs Oxya hoppers started their backward journey and were found taking shelter at a height, lower than the roosting position. Since it has already been observed that the hygropositive reaction tended to become intense at high light intensity or high temperature, it may, therefore, be suggested that the descent was due to high humidity at such a height under the water-logged conditions. Such a contention is more plausible as the temperature during the period September to March, at any one time, was never higher than 35°C. However, sometimes the adults were collected from an adjacent sugarcane field where they might have been in shelter between 11.00 - 14.00 hours.

The observations made on the seasonal life history of Oxya velox Fab. revealed that there were two generations in a year. There was a substantial support from the laboratory experiments that the favourable period for hatching was the monsoon season, and the peak winter or summer is passed over by the prolongation in the nymphal duration, longevity of the adults and the incubation period of the eggs. As it has already been observed that the prolongation is caused under both the circumstances namely low temperature and scarcity of the preferred food plants.

As a general practice around the experimental field the paddy crop is alternated with T. alexandrinum, a fodder, which requires water in almost equal abundance as paddy. Hence at any one time the environment does not offer such a stress as, very low relative humidity. Besides, ample of Cynodon dactylon and other common weeds are neglected as T. alexandrinum happens to be a fodder crop. Thus Oxya velox under such conditions never once faces the abrativeness of the environment.

CHAPTER - VI

S U M M A R Y

The smaller rice grass hopper Oxya velox Fab. is a paddy pest and is found in the humid tropical habitats of the eastern hemisphere including India. In India it is widely distributed and has been reported from several rice growing states including Uttar Pradesh. A search for Oxya velox through several crops in and around Cheherat village (Dist. Aligarh, Uttar Pradesh) revealed that it infested only Oryza sativa and could rarely be collected from Zea mays, Triticum aestivum or Sacharum officinarum. In some areas its infestation was also recorded on Sorghum vulgare, Pennisetum typhoideum and Trifolium alexandrinum along with Echinoclos colonum, Hemarthria compressa, Setaria verticellata and Cynodon dactylon among the weeds, which are commonly found in the paddy field.

In general both males and females are medium to small sized, females being slightly larger than the males measuring 2.73 cms and 2.48 cms respectively. There is a broad brown band extending from the upper half of the eye to the base of the tegmina; vertex often with two diverging brown lines and some times the middle of the vertex and pronotum filled-up with a brown band. Tegmina is longer than the hind femora which is expanded ventrally. Hind tibiae, beyond the middle, and the first tarsal joint considerably expanded. Hind tibiae are green with two rows of brown tipped spines on the margins of the expanded ventral surface. The newly emerged adults are green in colour with the dorsal pigmented band whitish green which turns brown after 4-7 days of emergence. The bright pigmentation diminishes with the advancement of age and just a day or two

before death they become almost brown. The change in pigmentation is more pronounced among the females than the males. Under the constant ecological conditions of 30°C Temp. and 70 ± 5% R.H. while fed on Cynodon dactylon. The longevity of the males is greater than the females being 39.90 ± 1.57 days and 29.90 ± 1.0° days respectively.

Males and females both do not start copulation immediately after the emergence. The male advances towards and touches the female with the antennae, and if the latter does not move away then the male mounts over the female with its forelegs at the frontal region while the claws grasp the lower margins of the frontal lobes. The middle pair of legs holds the female under its wings above the hind pair of legs. The hind legs do not take any direct part in the whole act. Now the male abdomen is curved downwards and its tip is brought below the abdomen of the female. The aedegus is protruded and inserted between the ventral oviporitor valves. The male cerci clasp the subgenital plate of the female and the more firmly near its base. The females with males in copula may continue to feed, crawl or even jump on disturbance.

The act of copulation is completed in two to four hours and is repeated several times. The females are copulated before or after each oviposition. The frequent copulations are not necessary for the successive ovipositions. The first copulation may be sufficient to fertilize the eggs in all succeeding ovipositions. However, the frequent copulations have a favourable effect on the fecundity.

The female at an average copulates 5 to 6 times during the whole life time and the average pre-copulation period is found to be 3.40 ± 0.15 days.

The female of O. velox Fab. deposites its eggs in the moderately damp soil and before oviposition makes a selection of the site with the help of the antennae, palpi and the ovipositor valves. The former two detect the moisture level and the latter, the compactness of the soil bed. A burrow 1 to 2.5 cm deep is prepared by inserting the ovipositor valves. The depth of the burrow depends upon the extension of the abdominal inter-segmental membrane. The average pre-oviposition (maturation), oviposition and post-oviposition periods are 9.0 ± 0.39 day, 17.0 ± 1.60 days and 3.8 ± 0.31 days respectively.

The whole compact mass of eggs enclosed inside a frothy secretion hardened and mixed with sand is known as egg-pod. It is dark brown in colour and is usually cylendrical towards its posterior while the anterior end is pointed. The egg-pod measures 1.4 to 3.6 cm long and 0.4 to 0.9 cm in diameter and is usually 2 to 3 chambered. The average number of eggs in each pod is found to be 9.00 (range 7.0 to ~~10.8~~ 14.00) and the average number of egg-pods per female is 6.20 ± 0.41. The total number of eggs laid by a female in its entire life time averages 56.40 ± 3.92 at 30 ± 1°C with 70 ± 5% R.H. and fed on Cynodon dactylon. The eggs are mostly placed in 2 rows, glued together with the frothy secretions of the pod. The egg is elongated and cylindrical, roughly banana shaped measuring 0.392 cm long and 0.118 cm in diameter. The egg gradually increases in

size as the embryonic development proceeds and measures 0.416 cm x 0.132 cm on the 17th day of incubation. The average incubation period is found to be 20.60 ± 0.42 days and the average percentage of hatching is 89.1 ± 2.30 under the constant ecological conditions (30 ± 1°C and 70 ± 5% R.H.).

All the larvae emerge from a pod in about 10 minutes, each enclosed in a thick membrane which is cast off immediately and is called as intermediate moult. These vermiform larvae are actually the first instar hoppers and are green coloured, measuring 0.49 cm in length. Antennae are 0.13 cm long and 12.00 segmented. There are no traces of the wing pads and genitals appears rudimentary.

The newly emerged hoppers are negatively geotropic and start feeding after about 4 hours of the emergence. The hoppers undergo six moults to reach the adulthood. An additional moult may rarely be observed among the females only. The duration of the first, second and third instars is slightly longer in the females than the males. The difference is quite prominent in the last nymphal instar where female hopper takes 11.00 ± 0.20 days while the male 8.80 ± 0.17 days to become the adult. The hoppers stop feeding about 16 hours before the moulting and take about 15 minutes to cast off the old cuticle. Proper perching and sufficient space is required especially for the final moult, otherwise deformity occurs, particularly in the wings. The female hoppers are slightly larger in size than the males with the total nymphal duration being 41.00 ± 0.48 days and 38.00 ± 0.39 days respectively.

The hoppers are green in colour with a broad white band running from the base of the eyes to the metanotum along the mid dorsal line. Two doted pigmented lines run almost parallel to each other along the sides of the band till the last abdominal segments. As the development proceeds, hoppers keep increasing in size, white band extends and becomes more prominent while the pigmented lines get diminished. The wing buds start appearing from the third instar but the orientation of the wings starts from the fifth instar.

A study was made of the importance of food plants in the ecology of Oxya velox (Fab.). The food preference tests revealed that Oxya velox (Fab.) is a selective feeder and the preference of food changes with the development. The food plants arranged in the descending order of favourableness for development were; mixed diet (O. sativa, E. colonum and C. dactylon); Oryza sativa; Cynodon dactylon; Triticum aestivum; Echinocloa colonum; Hemarthria compressa; Setaria verticellata; Zea mayes and Pennisetum typhoideum while Trifolium alexandrinum was not nibbled at all. The preference of the food is based upon a factorial-complex including the physical factors, availability of plants and lastly the chemical composition. The early instar hoppers prefer the weeds while the preference for the cereal crops increases as the development proceeds. Thus the removal of weeds from the field could check the population to some extent. Pennisetum typhoideum being the least preferred food adversely affected the fecundity which was reduced to 1[illegible] eggs per female as against 80.7 ± 0.[illegible] eggs per female on the mixed diet that was the most preferred one.

The effect of some ecological factors on the various developmental stages was studied by exposing eggs, hoppers and adults to 10°, 15°, 25°, 30°, 35°, 40° and 45°C temp. and 40 ± 5%, 70 ± 5%, and 90 ± 5% R.H. The eggs were also incubated with 0.0%, 8%, 12% and 25% contact moisture.

The developmental rate of the eggs is enhanced with a rise in temperature but percentage surval declines suddenly beyond 35°C. The most suited conditions for the development of eggs were 35°C temp. with 12% contact moisture. Too low (0.0%) or too high (25%) a level of contact moisture resulted in total egg mortality. The first 10 days after the oviporition were important when sufficient amount of contact moisture was necessary for the development. The development is also affected by the fluctuating temperatures. Short exposure to 5°C acted as a stimulus for the development while on increasing the exposure time, the same temperature became fatal. The eggs in the advanced stages of development were not affected so adversely by an exposure to the lower temperature as there in the early stages of the development.

The development of the hoppers was affected in a similar manner where the rate of development was directly related to the temperature. The effect of the humidity was obvious in two ways. Firstly the survival range of temperature was greatly reduced at 40 ± 5% R.H. and secondly a greater number of hoppers survived at higher R.H. at any level of temperature. The hoppers could not survive at 45°C irrespective of the R.H. conditions. The most suited

conditions for the hoppers were 35°C with 90 ± 5% R.H. The conditions of temperature and R.H. short of optimum, affected male hoppers more adversely than the female hoppers.

Temperature and humidity both significantly affect the development of the adults. Maturation of the gonads was in direct relation with the rise in temperature. 10°C was unfavourable for the normal reproductive activity and also at 45°C, the females could oviposit only when relative humidity was 90 ± 5%. Relative humidity did not effect the maturation period or the oviporition period except at the higher extreme of the survival temperature. The fecundity was highest at 35°C with high humidity. Low R.H. (40 ± 5%) reduced the egg production while at 70 ± 5% or 90 ± 5% it remained almost the same. The maximum number of eggs obtained was 64.90 ± 1.09 at 35°C as against 80.7 ± 0.89 eggs/female at 30°C when fed on the mixed diet. Within the range of 15°C to 35°C the rise in temperature increased the egg production but a further rise to 40°C or 45°C reduced it markedly. The effect of temperature on the longevity was a bit different. At 10°C the adults survived for a short period, maximum being 15.00 ± 0.82 days and 13.90 ± 0.94 days at 90 ± 5% R.H. for females and males respectively. Life span was longest at 15°C for both the sexes which reduced with the rise in temperature but, between 30°C to 35°C it was not affected by the change in temperature. It was only 40 ± 5% R.H. which reduced the life span at each temperature, otherwise R.H. levels 70 ± 5% or 90 ± 5% did not have any effect. The maximum percentage survival was obtained at 30°C to 35°C with 70 ± 5% or

90 ± 5% R.H., below or above this level it was reduced. However, it was interesting to note that the adverse conditions reduced the egg count and not the ovipositional instances.

The reactions of all the nymphal instars to a gradient of humidity temperature and light were studied in an alternative humidity chamber. The hoppers of Oxya velox (Lab.) preferred the wet half of the chamber and the intensity of positive reaction was further increased either at high light intensity, high temperature or both. The hopping activity was more among the early instar hoppers than the late instars. The general activity along with hopping was influenced by high light intensity and high temperature both. While klinokinesis was primarily influenced by the humidity. Since an increased activity was attributed to the unfavourable conditions of light, humidity or temperature, it was observed to be minimum in the wet half of the chamber as the hoppers did not feel agitated. The time spent active as against the total time spent in each half was always more in the dry half of the chamber but a definite decrease in activity was observed at 15°C or 0.7 L.F.I. (low light intensity).

The behaviour of the hoppers in the field was random and undirected. The awakening activity was followed by an ascent before the feeding started. Once again around the mid-day there was a descent and the hoppers as well as adults were found seeking shelter under the leaves. When the temperature started falling around 4th hour, another spell of activity was observed and the insects were found feeding. During the entire survey none of the hoppers were

found resting on the exposed surface of the leaf. The general activity among the hoppers was maximum in the early morning hours and at dusk.

Hatching in the field occurred in the mid of July through the later half of August reaching its peak till the 30th August. During the rainy season the females out numbered males by 3:2. Throughout the year emergence occurred thrice being maximum out of the eggs laid by the first generation females during October through November. The highest peak for the females was on 30th August while that of males on 30th December. There is no diapause among Oxya velox Feb. instead the adverse conditions are passed off by a decrease in the rate of the developmental processes.

The present study further revealed that Oxya velox Feb. is quite vulnerable as far as the stresses of the environment are concerned and probably due to this characteristic it remained as a sporadic pest in Aligarh District, Uttar Pradesh.

CHAPTER - VII

B I B L I O G R A P H Y

B I B L I O G R A P H Y

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